Materials & Methods

THE MAGAZINE OF MATERIALS ENGINEERING

Mechanical Fasteners

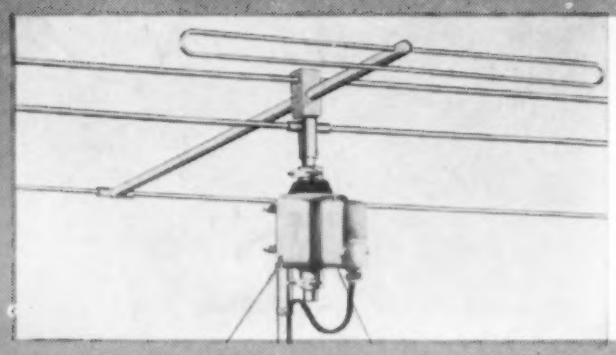
Materials & Methods Manual No. 51

July 1949

It pays to use your custom molder's know-how

say men who make television "beaming" devices

No. 7 in a series on Plastics Skill at Work . . .

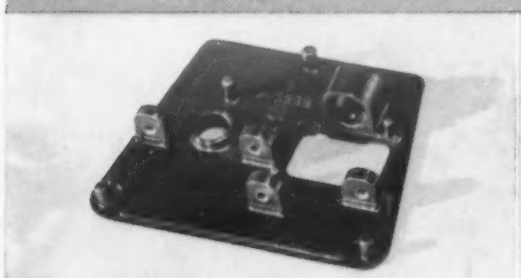


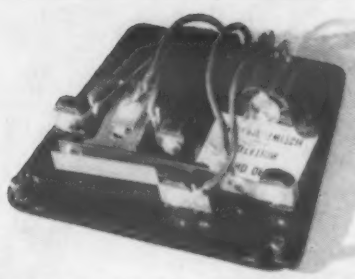
PROJECT: Two-piece control case to house transformer for antenna rotator.

CUSTOMER: Alliance Manufacturing Co., Alliance, Ohio.

MOLDER: Evans-Winter-Hebb Inc.

MATERIAL: Economical general-purpose Durez phenolic plastic.





ECONOMY: Molder eliminates many operations by producing electronic control case and face plate with lugs, bosses, cutouts, and inserts all "molded-in."

SPEED: Two-cavity compression mold with hydraulic cylinders for coring holes maintains high output. Front panel is a four-cavity mold. Loose wedges form light bulb socket hole.

At first glance this control box looked like a straightforward job of molding. Yet a small design change suggested by the molder points up a fact that is gaining wide recognition these days...

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In the *Tenna-Rotor,* Alliance Mfg. had developed a motor-driven TV and FM antenna rotation device that selects the exact compass point for optimum reception...strong signals, clear pictures. Armchair control was provided by a three-position switch in an attractive Durez plastic case.

Examining the blueprints, Evans-Winter-Hebb molding men saw eight tapped holes for mounting the transformer in the top of the control box. To provide a stronger and more durable and rigid mounting, they suggested that only four screw posts be used, and that these be molded into the Durez. Results: *one,* a more serviceable product, and *two,* a simplified assembly.

* * *

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THE MAGAZINE OF MATERIALS ENGINEERING

VOLUME 30, NUMBER 1 • JULY, 1949

FEATURE ARTICLES

MATERIALS & METHODS MANUAL NO. 51

ENGINEERING FILE FACTS

DEPARTMENTS

NEXT MONTH: Materials in the Aircraft Industry . . . Electrically Conductive Glass . . . Fast-Curing Thermosetting Plastic . . . Effect of Soldering on Sheet Copper . . . Surface-Hardening Gray Iron in the Flask . . . Drop Forged Steel for Stressed Parts . . . Scrap Aluminum for Die Castings . . . Welding Corrosion Resistant Steels

Published monthly by Reinhold Publishing Corporation, 330 West 42nd St., New York 18, N. Y., U. S. A. Ralph Reinhold, Chairman of the Board; Philip H. Hubbard, President; H. Burton Lowe, Executive Vice President; G. E. Cochran, Vice President and Secretary; W. P. Winsor, Vice President; F. P. Peters, Vice President; J. G. Belcher, Vice President; W. F. Traendly, Vice President; Francis M. Turner, Vice President. Price 50 cents a copy. Payable in advance, one year, $2.00; two years, $3.00; three years, $4.00; five years, $5.00 in U. S. and Possessions, Canada and Pan American Union, $2.00 extra for each year in all other countries. (Remit by New York Draft.)

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SLEEVE BEARING DATA

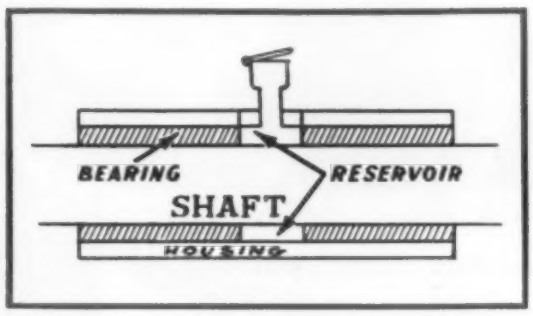
Bearing DESIGN

JOHNSON BRONZE

SLEEVE BEARING DATA

The Lubrication of Sleeve Type Bearings-2

NO BEARING, regardless of type, will operate satisfactorily or for any length of time without proper and dependable lubrication. The lubricant, as the life blood of every motive unit, should be the correct type, the right consistency and always in the right place at the right time. Otherwise excessive heat, wear and friction will develop with eventual seizure and bearing failure. The most popular lubricating agent is oil, with grease in some applications and graphite, water or other fluids used to a lesser degree.



In applications where it is necessary to use a longer than usual bearing, we sometimes recommend the use of two short bearings with the intervening space to serve as an oil reservoir.

The ideal bearing application is one in which it is possible to achieve a state of fluid friction with the journal and the bearing completely separated. The only friction present then is in the shearing action of the layers of oil. Obviously such an application would only be possible where there are high speeds and light loads. But as all bearing applications are not ideal, the designer must have ways and means to come as close as possible to ideal lubricating action.

Obviously, the first step is to assemble all operating facts. Then the method of distributing the lubricant and the type of lubrication to be used can be decided. Fundamentally, there are four primary methods of distributing the lubricant when it is oil —i.e., force feed . . . splash . . . bath . . . and ring, chain or collar oiling. In selecting the method to use, the most important factor to bear in mind is reliability.

Force feed is sometimes referred to as circulating lubrication. It includes all applications wherein a continuous flow of oil is maintained throughout all bearing applications. In such systems the viscosity of the lubricant is an important feature. It is also necessary to provide some method of purifying the lubricant for repeated use. Other considerations include speed, which should be high enough to build an oil film; dissipation of heat; prevention of leakage and oil oxidation. In some cases it is advisable to provide an oil cooling system to maintain the proper operating temperature of the lubricant.

The splash system involves the use of a completely enclosed crankcase, usually a cooling system and a heavy oil. As lubrication is effected by dipping, this system must provide an indicator so that the proper oil level is always maintained.

In the bath system the operating parts are usually completely submerged in the lubricant. In this method practically the same factors are involved as in the splash method.

Ring, chain or collar oiling involves a system whereby the lubricant is carried from the reservoir to the bearing by a ring or collar that rotates with the shaft to an opening in the top of the bearing. In this system particular attention must be paid to the type of oil grooving of the bearing so that sufficient oil is carried into every part of the loaded bearing area.

Hand oiling can be utilized in some applications although it is usually best to provide an oil cup or a combination of cup and wick.

Up to this point methods of supplying oil lubrication have been outlined. However, in many applications, use must be made of grease due to the nature of the operating conditions. Grease is ordinarily used for rough machinery where usage is severe and clearances are not consistent, and in slow moving equipment since the laws of hydrodynamic action are ineffective.

It is recommended that greases be supplied by some pressure system or pressure guns, since adjustable grease cups give positive action.

In conjunction with lubricating systems consideration must also be given to prevent end or side leakage. This condition in bearings is undesirable because it reduces the load a bearing may safely carry and results in extensive oil waste which creates problems of cleanliness both on the machine and goods in process.

In order to prevent this condition use should be made of proper oil seals which, in addition to conserving oil, keep dirt from entering the machinery.

In all applications in which lubrication is required it is desirable that repeated use be made of the lubricant for reasons of economy. However, it must be remembered that oil is certainly to become contaminated while it is being used and this contamination definitely reduces the effectiveness and efficiency of the lubricant, resulting in injury to bearing surfaces.

Air, in the presence of hot oil, results in oxidation and the formation of sludge. These sludges are often acid in character and are injurious to the bearing linings. In many applications water is prevalent and in mixing with the lubricant tends to dilute the lubricant and make it ineffective as a load carrying medium. In addition, high temperatures are extremely destructive to oils and cause vaporization of the lighter constituent and the formation of carbon. In order to assure clean, suitable oil, two methods are generally used, that of filtering or separation by gravity.

Obviously some methods of lubrication are more expensive than others. There are many ways of reducing costs in designing machinery but the selection of an inferior or inadequate system of lubrication is not one of them. The most expensive bearing in the world is the one that fails. The easiest way to be certain of getting the greatest value and performance out of your bearing applications is to consult with Johnson Bronze. Our engineers are fully competent to give the proper advice and assistance on all your bearing problems. They will work with you without obligation.

In some bearing applications it is often possible and practical to provide recesses on the outside diameter of the bearing which serve as oil reservoirs.

This bearing data sheet is but one of a series. You can get the complete set by writing to—

EDITORIAL

Informative Labeling

To the general public, "plastics is plastics". Mr. Little Consumer would be surprised indeed to learn that there are literally 101 different plastic materials. Because this situation exists, the Society of the Plastics Industry should be lauded and encouraged in its informative labeling program, which is now ready to go into high gear.

Most of us have, at one time or another, purchased some plastic gadget which failed to survive what we assumed to be normal usage. Perhaps it was our fault; perhaps it was the plastics. Regardless of the fault, we were still a little leery when next we came in contact with any plastics object.

Now, the SPI is enlisting the cooperation of everyone involved in making, distributing and selling plastics products in a campaign to label every product intelligently. Materials producers are to work with consumers of the raw materials so that first of all they do not misapply the materials. Second, the ultimate sellers of the products are to participate so that they do not get overenthusiastic in their claims.

If the manufacturers or distributors of the products follow the SPI's plan, their products will bear labels telling: (1) What it (the product) is; (2) what it will do; (3) what it is made of; (4) how it is made; (5) how to take care of it; and if apt, (6) guarantee.

A few years ago, some government bureaus were trying to make grade labeling of foods and some other products mandatory. Steps like this taken by technical societies and business associations are the best methods of forestalling further government control.

It is likely that other materials groups might be smart to adopt some sort of informative labeling. For instance, stainless steel requires certain precautions to keep it gleaming, but most consumers of the ultimate stainless steels products do not know this. Even products made of ordinary steel could be made to give better service if the buyer is told how to protect the steel from rust and how it can be cleaned if it should rust.

Whether or not this movement goes far, the mere fact that the SPI is pushing informative labeling in its own field is a step in the right direction. Perhaps the time, money and headaches saved by the program will inspire others to follow suit.

T. C. Du Mond
Editor

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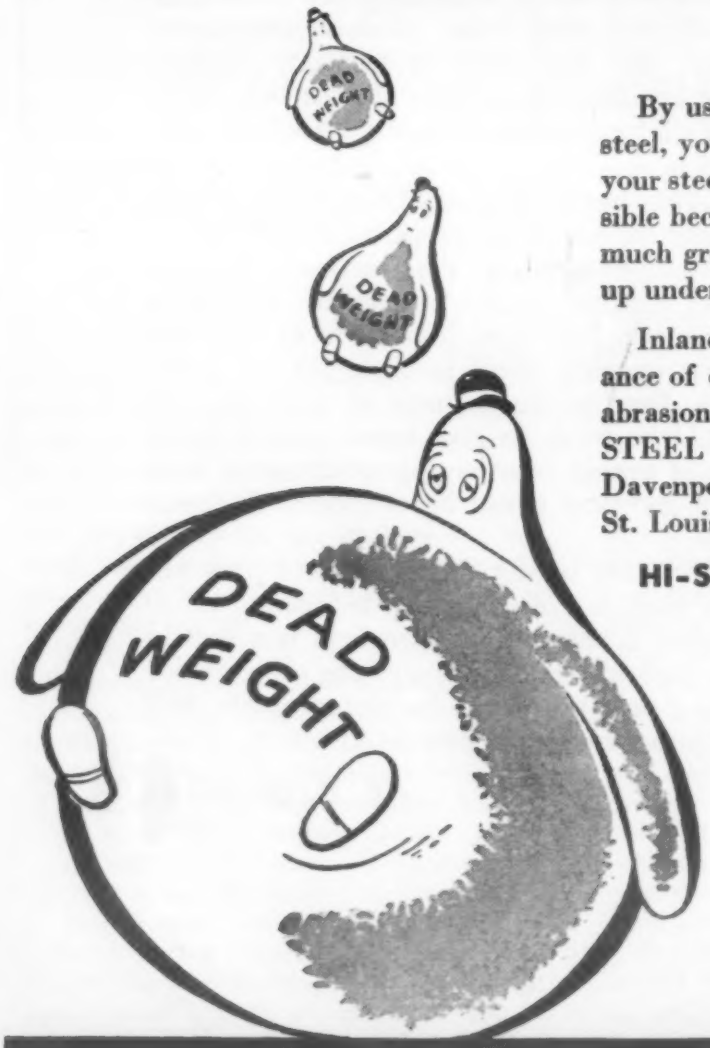

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Materials & Methods
JULY 1949

How to Select Anode Materials for Cathodic Protection Against Corrosion

by N. BRUCE BAGGER, Associate Editor, Materials & Methods

Intelligent use and selection of galvanic anodes, or waster plugs, greatly reduces electrolytic corrosion in many types of equipment.

● CORROSION, and its attendant losses, costs millions of dollars a year. This loss could be materially reduced by proper preventive measures. Cathodic protection is outstanding among these preventives and can be used effectively to combat the ravages of corrosion in many different applications.

Corrosion on the inside of domestic hot water tanks, superheaters, heat exchangers, etc., and on certain marine equipment such as rudders and ship plating is a result of galvanic action of dissimilar metal couples, or potential differences on the surface of the metal. A reaction takes place between the water and the metal surface and sets up a current flow from the anodic to the cathodic areas. As a result, the anodic areas lose metal and corrosion occurs.

In certain buried metal structures, such as domestic oil tanks, sewers, conduits, etc., exterior corrosion results from electric current flowing from the metal into the adjacent soil. This current is produced at the surface of the metal from action between the metal and chemicals in the soil, from galvanic corrosion, or from stray current from an adjacent d.c. electric system.

Cathodic protection for these corrosion difficulties is achieved by impressing inward-flowing currents to counteract, and thus prevent, the outward-flowing currents of corrosion. In principle, this electrochemical action is essentially the same as that of a common dry cell. The externally-supplied energy can be obtained from either of two current sources: (1) Where high current is required, d.c. generators or rectifiers connected positively to the electrolytic anode and negatively to the protected material can be used; (2) where less protective current is needed, galvanic anodes or waster plugs can be used Since these plugs or rods supply a galvanic potential to combat the currents of corrosion, they are naturally dissolved by the protective current they discharge and must be renewed at intervals. But under favorable conditions, these types of anodes last several years before replacement becomes necessary.

Selection Factors

When selecting specific metals for use as galvanic anodes, certain of their properties and characteristics should be considered. Among these

are the following: (1) the potential of the anode metal with respect to that of the metal to be protected; (2) the electrochemical equivalent of the anode metal; (3) the polarization characteristics of the anode metal as affected by time, environment and anode current density; and (4) the uniformity of the anode metal composition.

The metal selected must not only be anodic to the protected metal, but the potential difference developed must be sufficient to properly polarize the local cathodes of the protected metal. Additional voltage impressed provides increased "throwing power", reduces the number of installations required, and correspondingly reduces installation costs.

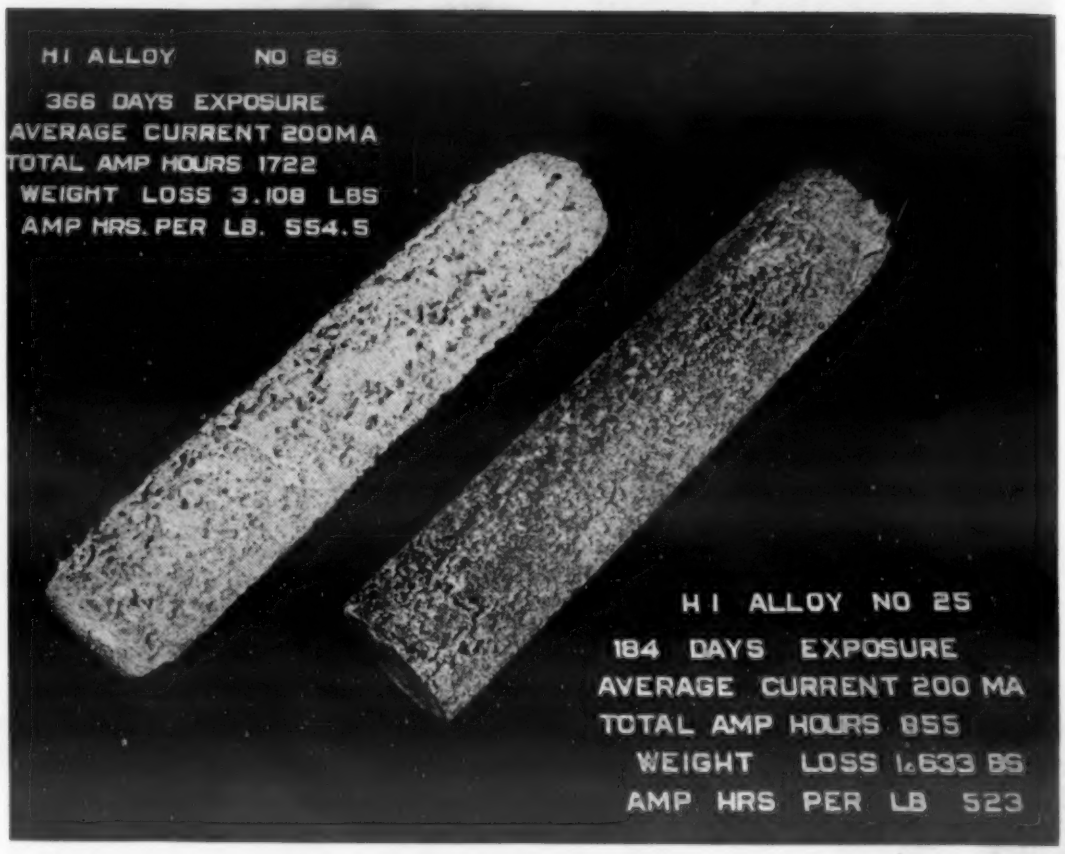
The following table gives the electrochemical equivalents of three commonly-used anodic materials:

Metal	Gm. per Amp.-Hr.	Lb. per Amp.-Yr.	Amp.-Hr. per Lb.
Zinc	1.22	23.5	372
Magnesium	0.45	8.8	1000
Aluminum	0.33	6.5	1352

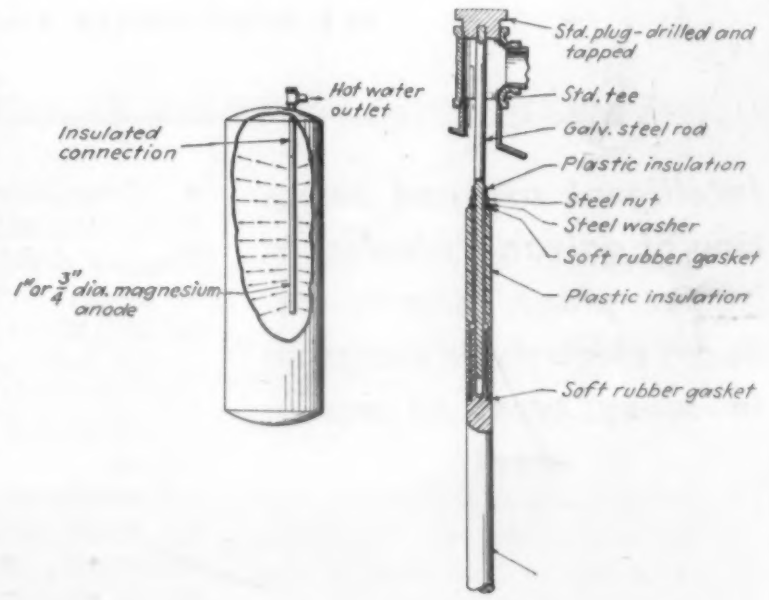
But these theoretical current yields are seldom realized in actual practice because of side reactions. Thus, there is a need for determining current efficiency and the effect of operational and environmental factors.

As a general rule, the most desirable anodic materials exhibit a minimum of polarization with respect to time and current density; many galvanic anode installations operate for periods up to 5 or 10 yr. without replacement of anodes, or wasters.

Uniformity of consumption is essential for maximum anode life, current efficiency, and energy recovery. If high current efficiencies are achieved at the expense of corrosion uniformity, the losses arising from anode segregation can more than offset any gain derived from the increase in efficiency.



Condition of the magnesium anodes of different compositions after completion of tests simulating service conditions. Note irregular depth of corrosion. (Courtesy Dow Chemical Co.)



Magnesium anode installation in outlet of water heater tank. Outlet diameter limits diameter of anode. More central installation away from outlet would permit larger diameter anode to be used and result in more uniform coverage of protected surface. (Courtesy Dow Chemical Co.)

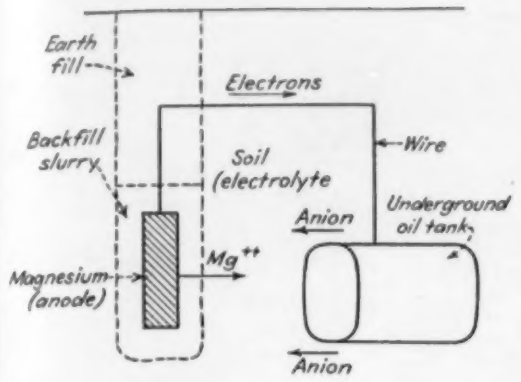
Magnesium

Magnesium, because of its high anodic position in the EMF series, is admirably suited as an anodic material. Electrical output of magnesium is theoretically 1000 amp.-hr. per lb. With the exception of lithium, this is a larger capacity than that of any other metal of comparable driving power, and magnesium shows little tendency to polarize.

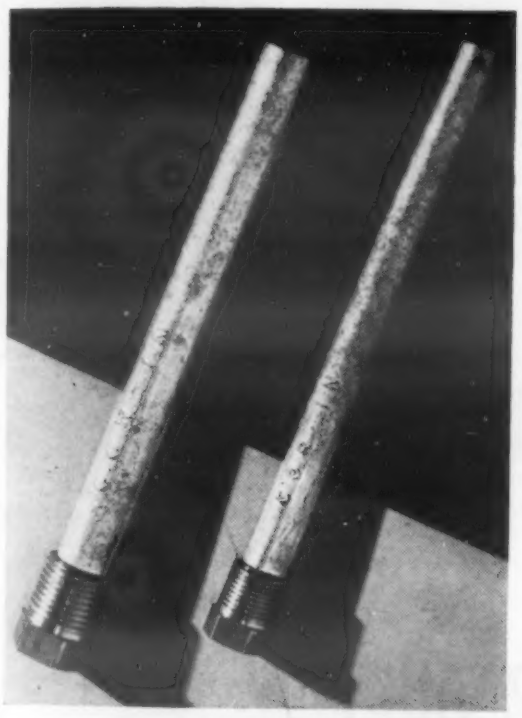
Commercially pure magnesium has a 0.1-v. higher solution potential than its commonly-used alloys. But it is more subject to lower current efficiencies and correspondingly shorter life. In alloying, some of the voltage is sacrificed. But this loss is more than compensated by increased efficiency and prolonged anode life. A special magnesium alloy of high current efficiency has been developed for anode use. The composition limits of this alloy are: 5.6 to 6.7 aluminum, 0.18 manganese, 2.5 to 3.5 zinc, 0.3 silicon, 0.05 copper, 0.003 nickel, 0.003 iron, 0.3% other impurities, and the balance magnesium.

An important use of magnesium anodes is in domestic hot water tanks and similar steel structures. The degree of corrosion control achieved here is affected by many factors. Among these are: (1) rate of water change in tank, (2) amount and nature of dissolved solids, (3) concentration of dissolved gasses, (4) current flow from the anode as determined by the electrical conductivity of the water, and (5) the water temperature in the tank.

Although zinc galvanizing is customarily used in these tanks to inhibit corrosion, it is not always possible to obtain a perfectly continuous coating. Minute pin holes expose the bare steel, and as the zinc eventually dissolves, corrosion of the steel takes place. The protection afforded by the magnesium anodes is largely confined to the tank alone. The protective cur-



Typical protection of buried metal structure by magnesium anode. Use of backfill slurry reduces the anode resistance and increases its current efficiency. (Courtesy Dow Chemical Co.)



Threaded into the walls of tanks, heat exchangers and similar structures, these zinc rods fitted with standard pipe-plug ends adequately protect the interior surfaces against corrosion. (Courtesy Rotometals, Inc.)

rent is not sufficient to penetrate far into the piping that conveys water to and from the tank.

The magnesium anode is usually installed in as nearly central location in the tank as possible in order to obtain equitable distribution of current. And since the magnesium usually connects to a dissimilar metal in the tank head, or wall, protection against galvanic action should be made at this point to prevent the anode from "necking off."

When magnesium anodes are used to protect buried metal structures such as domestic oil storage tanks, sewers, piping or conduit, the resistance of the soil determines the current efficiency and anode life. Among the advantages of magnesium anodes for this type of installation is the self-regulation of current output. As the current demand decreases due to polarization of the buried structure, the current output of the magnesium automatically decreases. Another advantage is magnesium's comparatively low driving potential. This prevents injury to the structure coating caused by application of over voltage.

Aluminum

Aluminum is a good anodic material for cathodic protection. But where an external source of d.c. power is applied, anodes of aluminum-copper alloys such as 17S-T and 24S-T are superior to either commercially pure aluminum or the aluminum-zinc alloys. These aluminum-copper alloys have certain inherent advantages when used as anodes with applied current. One is their low electrochemical equivalent. With 100% anode current efficiency, a smaller weight of aluminum will be dissolved per amp.-hr. than in the case for any any other appropriate metal. The corrosion products of aluminum are white or colorless, and adhere to the anodes after forming. This prevents discoloring or contamination of the electrolyte; particularly important when the anodes are installed inside water storage tanks. Another advantage is aluminum's uniform dissolving rate. No deep pits develop on the surface of the anode, and no film of high resistance forms to limit current flow. The light weight of aluminum anodes is also an advantageous factor in reducing costs incidental to the installation of the wasters.

High-purity zinc is also used for cathodic protection purposes. But the resistance of the electrolyte assumes greater importance when zinc anodes are used since a highly resistant electrolyte will inhibit the galvanic deterioration of the zinc. Where this resistance amounts to several thousand ohms per cu. cm., zinc is not usually economically feasible since the great area of zinc that would be required for satisfactory results would prohibit its use.

Steel and Iron

Anodes of steel, cast iron and carbon, each with current supplied from an external source, are sometimes used for cathodic protection purposes. But they have several disadvantages. Iron is usually unsuited because of its high electrochemical equivalent, about 20.2 lb. per amp.-yr. Iron or steel anodes, big enough to last several years at customary current densities, are much too heavy for easy installation. Such anodes also develop localized pitting attacks. Carbon anodes, although sometimes used, are impractical from an installation standpoint because of their mechanical properties, and they require considerably more work to install than the other customary types.

A comparison of the three major anodic materials per quantity of current supplied is important from a cost standpoint. In this, a convenient quantity of current to use is the amp.-yr. The following table shows the approximate cost per amp.-yr. of different forms of magnesium, aluminum and zinc. The calculations in this table are based on 100% current efficiency, and the costs are based on carload lots.

From this it would appear that the cost of current at 100% current efficiency from an aluminum anode is always lower than that from either magnesium or zinc. However, as mentioned before, much depends upon the resistance of the electrolyte. In certain installations, for instance, magnesium anodes will deliver more current per anode of given surface area than either aluminum or zinc.

It is obvious, therefore, that before any material is selected as the anode for cathodic protection, considerable study should be made of all the factors affecting its use. No one set of rules will apply in all installations. In the past, zinc anodes have enjoyed considerable popularity. But in recent years, the light metals and their alloys have proved to have several fundamental advantages. None should be overlooked in selecting the proper anode material.

Metal	Lb. Metal per Amp.-Yr.	Cost per Amp.-Yr. in Dollars			
		Pig	Plate, ½ In. Thick	Rod, 1½ In. Dia.	Bar, ½ by 3 in. Rectangular
Magnesium	8.8	1.804	4.136	3.196	4.444
Aluminum	6.5	0.910	1.378	1.495	1.593
Zinc	23.5	2.174	2.938	3.466	2.938

(Table courtesy National Association of Corrosion Engineers)

A group of turbo mixers of 18:8SMo casting alloy used in chemical processing.

Molybdenum-Bearing Stainless Casting Alloy Has Wide Range of Uses

by **NORMAN S. MOTT**, Chief Chemist and Metallurgist, The Cooper Alloy Foundry Co.

The addition of molybdenum to conventional 18:8 stainless steel has produced a popular casting alloy with improved corrosion resistance, and increased strength at elevated temperatures.

● THE MOLYBDENUM-BEARING chromium-nickel alloy, designated CF-8M by the Alloy Casting Institute, is receiving ever wider use in industry because of its set of unique and useful properties. It is estimated that around one-third of the stainless steel casting industry's current 18:8S stainless steel output is in alloy type CF-8M. In the past year, several companies specializing in the casting of stainless have announced that anywhere from 50 to 80% of their 18:8S output has been produced in this alloy. The purpose of this paper is to present data covering its properties and types of uses so that a clear overall picture can be had of the alloy's range of applications.

Corrosion Resistance Properties

Alloy CF-8M is a modification of the conventional low carbon 18 chromium: 8% nickel alloy, so commonly used in the corrosion resisting alloy field for many years. The addition of molybdenum, which distinguishes this alloy, tends to enhance corrosion resistance and raise the strength at elevated temperatures. Molybdenum increases its passivity under mildly

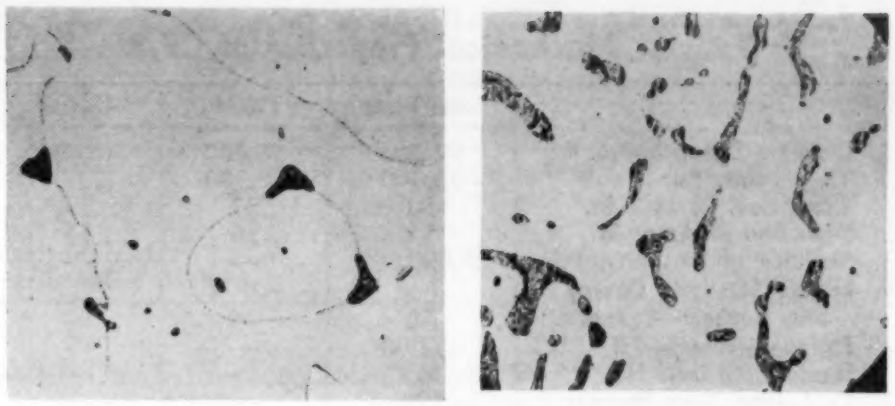
oxidizing corrosion conditions, improves its inherent corrosion resistance in reducing media, lowers its susceptibility to intergranular corrosion after critical heating, such as would result from a welding operation, and produces practical immunity to the pitting type of corrosion caused by sea water and chloride chemicals.

Passivity, a surface characteristic of nobility and low corrosion rate, is maintained with a 2% and upwards addition of molybdenum under many practical corrosion conditions; however, when the molybdenum content exceeds about 3%, an excessive rate of corrosion results in the boiling 65% nitric acid test commonly used for 18:8 type alloy acceptance. Therefore, 3% is taken as the maximum in most specifications.

Molybdenum additions of 2 to 3% are also quite effective in reducing susceptibility to the intergranular type of corrosion, being about as potent in this respect as columbium additions in its usual amount (*e.g.*, 8 x % C). In a great variety of corrosive media, this obviates the necessity of heat treatment after welding operations; however, in the sensitized condition, the general corrosion resistance to boiling 65% nitric acid is low. Thus, CF-8M is not recommended for use in hot nitric acid unless a quench anneal heat treatment is given after welding operations. Double additions of columbium along with the molybdenum are of no greater benefit than molybdenum alone in preventing intergranular corrosion, and are exceedingly bad in general corrosion resistance, giving very high rates in the boiling 65% nitric acid acceptance test. It may be stated at this time that a columbium addition alone offers no resistance to any corrosive media, and it is added for the purpose of intergranular corrosion prevention alone.

The pitting type of corrosion in stainless steels is caused above all by the halides and their wet salts, or salt solutions. Molybdenum additions to 18:8S are of special value in avoiding this form of corrosion. Of various grades of stainless compositions, the CF-8M alloy has the highest resistance. Almost complete immunity to pit corrosion can be accomplished by keeping the silicon content up to 2% in the CF-8M alloy, making it the equal in this respect to nickel and Monel.

CF-8M is superior to CF-8 and CF-8C in resistance to stress corrosion cracking; in this case, however, higher molybdenum percentages of 3 to 4% are better, and a stress relieving anneal at 1600 F improves resistance. This suggests the possibility of CF-8MC being most suitable for this condition, as the ferrite formation in the alloy, combined with uniform distribution of carbides, should promote the most resistance to stress corrosion cracking. Hot solutions of acidulated chlorides, especially zinc and magnesium, are the worst offenders in this form of corrosion failures.



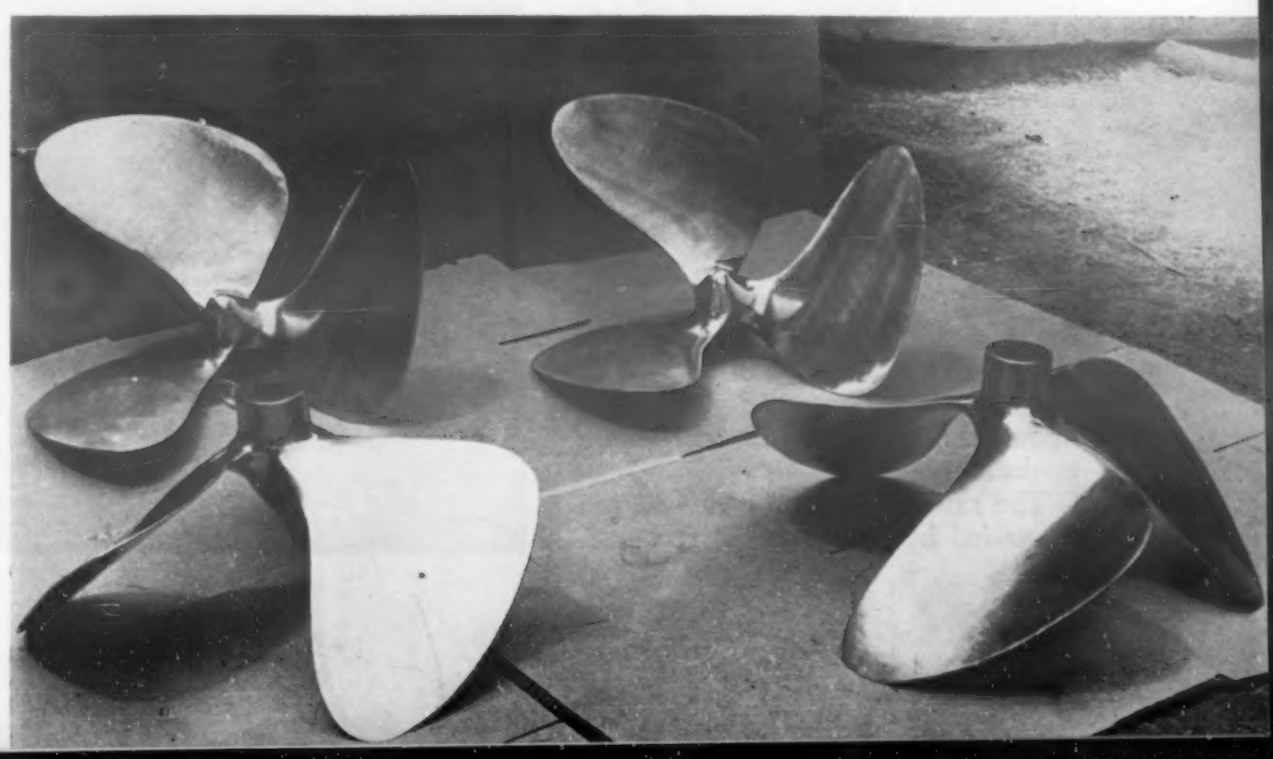
Typical microstructure of sensitized fully austenitic 18:8 alloys showing carbide precipitation at grain boundaries (left), compared to microstructure of sensitized ferritic CF-8M alloy (Mo 2.83) with carbide precipitation in ferrite pools (right). (Courtesy Alloy Castings Institute)

Molybdenum in itself rates high in corrosion resistance, and its inclusion in the 18:8 analysis imparts added resistance to many corrosive media. Use of CF-8M gives improved resistance in the following environments:

1. Organic acids or their vapors, especially when hot.
2. Cold and hot dilute solutions of sulfuric acid.
3. Phosphoric acid when concentrated and hot.
4. Fatty acids at elevated temperatures.
5. Solutions or vapors containing small percentages of chlorine, hydrochloric acid or other halogens and their acids.
6. Hot solutions of chlorides.
7. Acid salts or neutral salts, accompanied by a small percentage of acid.
8. Sulfurous acid solution at high temperature and pressures, or where small amounts of sulfuric acid may be present due to oxidation, as in the sulfite pulp processing liquors.
9. Hot strong caustic solutions.
10. Oxidizing alkaline or acid salts.

Aeration and turbulence of the corroding media often affect the rate of corrosion, and the presence of solid material may add erosion-corrosion or under-deposit pitting to the picture. Alloy CF-8M, unlike CF-8, is more resistant in agitated than in quiet solutions, and the addition of aeration causes little change in the corrosion rate. CF-8M is more resistant to erosion-corrosion than CF-8, and its superior resistance to the pitting type

These polished agitators of molybdenum-bearing stainless steel meet severe corrosion resistant requirements.



Mechanical Properties of CF-8M

	Room Temp.	1000 F	1200 F	1400 F
Ultimate Strength, Psi.	90,000	58,000	40,000	23,000
Yield Point, Psi.	55,000	18,300	17,000	14,200
Elongation, % in 2 In.	50	37	33	23
Reduction of Area, %	55	56	55	33
Modulus of Elasticity, Psi.	28,000,000	—	—	—
		–200 F		
Impact Strength, Charpy Std. Keyhole—Ft.-Lb.	60	45	—	—
Fatigue Strength, Psi.	45,000	—	—	—
Hardness, Brinell No.	155	—	—	—
Cold Bend Test, Degrees	180	—	—	—
		1000 F	1200 F	1400 F
Creep Strength, 1% Creep in 10,000 Hr., Psi.	—	24,000*	11,000*	4,000*

**Values for wrought Type 316 material—no data available for castings. Comparative values for 18:8 Type 302 are: 1000 F, 18,000; 1200 F, 7,000; and 1400 F, 2,000.*

Physical Properties of CF-8M

Specific gravity	8.00
Density, lb. per cu. in.	0.292
Melting point, solidus F	2500-2550
Specific heat, btu./lb./F 32-212 F	0.12
Coefficient of thermal expansion, 32-212 F	0.0000089
in. per in. per F 32-950 F	0.0000097
32-1200 F	0.0000103
Thermal conductivity, btu/sq. ft./hr./F/in. 212 F	108
950 F	145
Electrical resistivity, ohms/cir mil ft., 32 F	420

of corrosion has been previously pointed out.

Other Properties and Applications

Some concern is frequently expressed over the presence of magnetism in CF-8M. This magnetism is due to the presence of the metallographic constituent ferrite, which must not be construed as being detrimental, as 10 to 15% or more is necessary for a good resistance to intergranular corrosion, and up to 30% can be tolerated without being too detrimental to mechanical properties.

Unless the concentration of certain elements are adjusted outside the CF-8M specification range, molybdenum causes the formation of ferrite in the microstructure, and the alloy becomes a two-phase alloy, with the austenite predominating. Consequently, CF-8M can show gradations in microstructure and magnetism, depending primarily upon the chemical composition. Estimation of the approximate amount of ferrite present in CF-8M and other similar alloys can be accomplished by the use of a phase diagram based upon the nickel and chromium equivalent values.

The microstructure of CF-8M can be varied by the chemical composition, as stated before, and can also be varied by heat treatment. No carbides to speak of are found in the quench-annealed condition. In the fully austenitic alloys, which have been sensitized by heating in the carbide formation range, carbide precipitation occurs preferentially at the grain boundaries in the form of a continuous phase which is mechanically weak and which allows rapid intergranular corrosion.

In the partially ferritic molybdenum bearing alloy, CF-8M, the carbides precipitate in the ferrite pools, which are not continuous, and therefore the alloy is not weakened mechanically or subject to corrosion attack of the intergranular formation when CF-8M is heated in this temperature range of 900 to 1600 F.

The mechanical properties of CF-8M at room temperature show good strength, ductility and toughness, the latter being maintained at a good level for subzero temperatures, a condition often found in present day chemical processing. As stated before, the addition of molybdenum to 18:8 raises the strength at elevated temperatures, the load carrying ability of CF-8M ranging from 50 to 100% over that of CF-8 or CF-20. This feature makes CF-8M desirable for use in corrosion resisting valves for high temperature and pressure service. In heat applications CF-8M should not be used above about 1600 F, as at this temperature the alloy starts to scale in air.

The machining of CF-8M is slightly more difficult than CF-8; however, a machine shop experienced and equipped to handle stainless should have little difficulty in this respect. Weldability is about the same as CF-8 and, as previously pointed out, the necessity of a post heat treatment to preserve corrosion resistance is obviated.

In conclusion, some notable uses for CF-8M are listed to show its versatility in many diversified corrosive applications:

Paper pulp digestor fittings.

Film developing parts.

Mine pumps handling erosive acid waters.

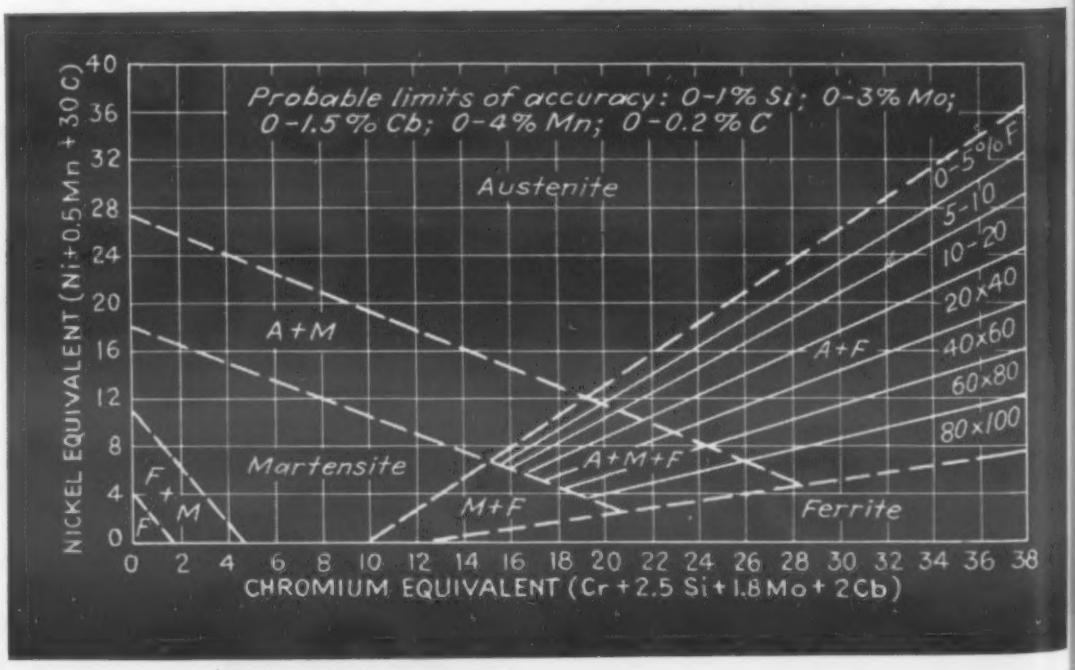
Handling products of combustion containing sulfur dioxide in the cooler sections of the system where condensation and severe corrosion may occur.

In the petroleum industry for pumps where brine is associated with crude oil.

High temperature corrosive valve service.

In the food industry for handling flavoring sauces or brines for pickles.

Phase diagram for chromium-nickel steel alloys. Approximate amount of ferrite present in CF-8M can be determined from this chart. (Courtesy Arcos Corp.)



Compositions and Designations for Alloy Casting Institute 18:8 Type Alloys

ACI Designation	Chemical Composition, %				Equivalent Designations		
	C	Cr	Ni	Other Elements	AISI	ASTM	Others
CF-20	<0.20	18-21	8-11		302	A296-46T G3	18-8 KA2
CF-8	<0.08	18-21	8-11		304	A296-46T G1	18-8S KA2S
CF-8M	<0.08	18-21	9-12	Mo 2-3	316	A296-46T G4	18-8SMo KA4
CF-8C	<0.08	18-21	9-12	Cb 8 x C 1.00 Max.	347	A296-46T G5	18-8SCb
CF-8MC	<0.08	18-21	9-12	Mo 2-3 Cb 8xC 1.00 Max.	—	—	18-8SMoCb

Equipment for handling corrosive paper bleaches or acid dyeing baths.

To handle nitrating acids for explosives.

In the ammonia soda process to handle ammonia-sodium chloride liquors.

To handle chlorinated solvents when moisture is present.

In the manufacturing of boric acid.

Susceptibility to Intergranular Corrosion of the Molybdenum Bearing Alloys as Compared to the Other 18:8S Types

Corrosion in Boiling 65% HNO_3 after Sensitization at 1200 F for 24 Hr.				
% Mo	% Cb	Corr. by Weight Loss	Corr. by Elec. Resis.	Ratio
0.00	—	0.01500	0.11200	7.46
1.00	—	0.00553	0.02100	3.80
1.40	—	0.00392	0.00900	2.30
1.83	—	0.04925	0.06720	1.36
2.50	—	0.07430	0.10700	1.44
5.00	—	0.24110	0.37900	1.57
—	.69	0.00432	0.00580	1.34
1.74	.74	0.15030	0.20270	1.35

Base composition 0.08-0.09 C, 19 Cr, 9% Ni. Ratio of corrosion rate by electrical resistance method to direct weight loss method when over 1.7 indicates intergranular attack. Corrosion values in inches penetration per month.

This nozzel for a vacuum pump, cast of CF-8M alloy, is subjected to steam at supersonic speeds. (Courtesy Croll-Reynolds Co.)

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Plastic Laminate for Cabinets Is Easily Fabricated

This wood-derived high pressure phenolic laminate, known as Micarta, is highly durable and can be accurately molded and easily fabricated at low cost.

by J. L. FEELEY, Design Engineer and C. J. RAPP, Manufacturing Engineer, Micarta Div., Westinghouse Electric Corp.

● RADIO, AIR-CONDITIONER and similar cabinets can now be made of a new Micarta material that combines the advantages of wood with those of high-pressure laminated plastics. Accurately molded sections of the laminate, either in flat pieces or embodying simple curves, permit assembly-line production of cabinets with complete interchangeability. Low fabricating and assembly costs more than make up for the higher initial cost of this material.

The new laminate is available in wood-grain finishes, in surface designs distinctive to the material itself, or in decorative finishes common to plastic materials today. Both sides of the material can be completely finished as it leaves the mold, and either satin or high gloss finish is obtainable. Molding the laminate in sections permits a varied contour and, if desired, different surface designs or colors can be employed on the various sections. A surface sheet of printed paper is commonly used with either phenolic or melamine resins; however, an actual wood veneer impregnated and molded can be used as the laminate

Record player cabinet disassembled showing Micarta panels that are used in its construction.

surface where the extra cost is justified.

Finished radio cabinets made of this laminate are practically indistinguishable from highly polished, best quality cabinet wood. At the same time they are resistant to scratching, alcohol, solvents, boiling water, and burning cigarettes. The molded surfaces made by the new technique have an abrasion resistance of five times the usual phenolic impregnated wood print laminates and eight to ten times the surfaces applied by roll transfer coating.

The laminate is composed of a number of sheets of phenolic treated kraft paper sufficient to give a desired thickness after molding, and on either side of this body stock are placed the special printed phenolic or melamine impregnated surface sheets. The built-up body and surface materials are then molded to close tolerances in chromium plated steel molds. The phenolic surfaced pieces are completely molded under high temperatures and pressures within 3 to 5 min. The melamine surfaces require a little more time, and both types are pulled from the mold hot.

The sections leave the mold with their outer and inner surface finish complete. Thus sanding, prime coating, hand roll wood print transfer, lacquer coatings, and drying as required to produce a less durable surface finish on plain laminates, hard fiber, or wood are eliminated.

The printed surface sheet can be made to represent any woods in the following cuts: rotary, half round, sliced or sawed, depending upon the type wood and in the following variety of figure: plain, quartered, ribbon or broken stripe, rope, roe, mottle, fiddleback, raindrop, fingerroll, curly, blister, bird's-eye, quilted and plumpudding. Color variation can be varied in the paper making, printing and impregnating operations.

Should the desired design not be available in the form of a printing roll, the design can be had by photographing a piece of the actual veneer and transferring the photograph to a printing roll by an etching process. Special surface paper is then printed, using an ink capable of withstanding the high temperatures and pressures of the molding process.

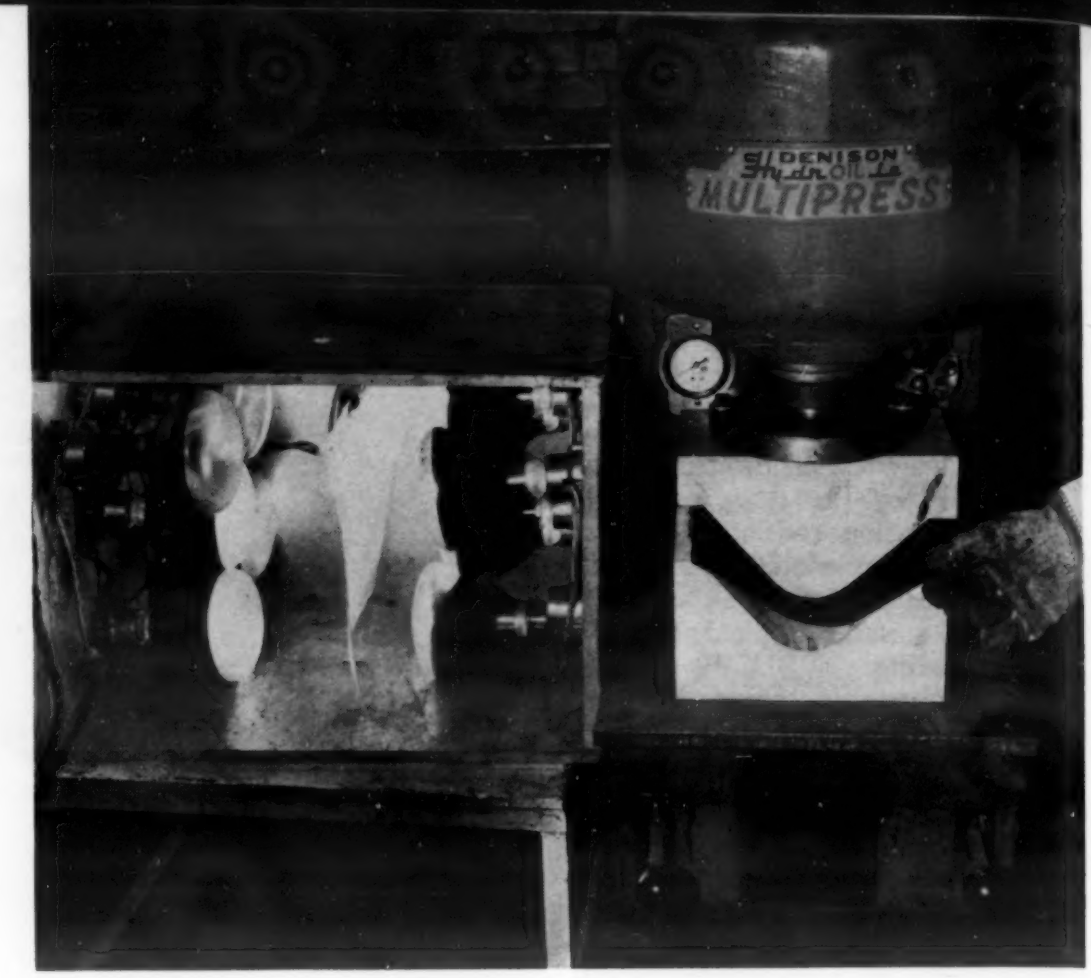
One operation in the production of Micarta is to press a build-up of phenolic-treated paper in a high pressure press. Molds are chromium plated.

Close tolerances can be held throughout such machining operations as drilling (shown here), and milling.

Fabrication Characteristics

Fabrication of the molded sections consists of straight and miter sawing, end milling, drilling and buffing. Close tolerances are held throughout the machining operations to insure interchangeability in assembly. After finish machining, the sections are shipped knocked-down directly to the assembly line where they are processed in very much the same way as radio chassis. The cost reductions in fabricating, shipping and assembly effect a considerable savings over the cost of wood cabinets.

A typical cabinet consists of five molded pieces. The molded pieces are first sawed to size. The side pieces of the cabinet are then miter sawed on



Infra-red heating and wooden molds can be used for postforming mock-ups.

the upper back edges. The lid is also miter sawed on the back edges to match the side pieces. The decorative contour on the side pieces are then machined on a pantograph machine by use of an end mill. This contour can be varied by simply changing the template on the machine.

Assembly, record changer mounting, wire cord mounting, and hinge mounting are drilled on multiple spindle drilling machines. The use of adjustable drill heads permit hole locations to suit the particular design with a minimum of set-up time. Finally, the five pieces that make up the cabinet are buffed to remove all sharp edges.

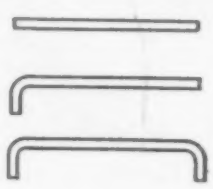
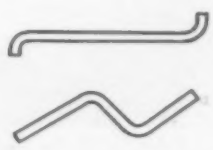
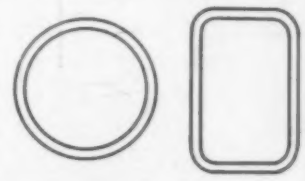
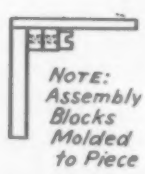
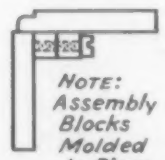
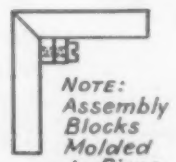
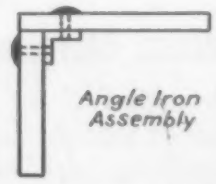
Assembly of the cabinet is made by first riveting a light weight "U" shaped angle iron frame to the front partition. This in turn is riveted to the side pieces, forming a base for mounting the record changer. The next step is to rivet a metal strip to each side of the back piece. The back is riveted to the assembly of the front and side pieces, completing the four walls of the cabinet. Next, hinges are attached to the lid and cabinet assembly.

All exposed rivets on the sides are counterbored and covered by a cemented leatherette strip. The back of the assembled cabinet has the same finished appearance as the rest of the cabinet. All visible hardware has been confined to this area and thus does not detract from the overall appearance.

Design of new cabinet models is aided by the quick development of mock-ups from low cost cast iron molds having chromium-plated pressing plates. Post forming by use of wooden molds is also used in making mock-ups.

Not only does this type of cabinet construction lend itself to considerable cost reduction as compared to wood cabinets, but difficulty experienced in matching colors and designs between cabinets when using scarce decorative woods is eliminated. The laminates are manufactured under controlled processes, providing uniform qualities and appearance in individual parts.

Properties and Characteristics of Micarta

Performance Properties	Tensile 16,000 psi. Compressive 38,000 psi. Flexural 27,000 psi. Shear 9,000 psi. Impact (Charpy) 9.0 ft. lb.	Moisture absorption: 1/16-in. thickness 2%. Does not swell	Heat resistance: distortion>320 F. Will withstand 180 C for 2 min. without blistering	Resistance to alcohol, solvents, fruit acids, cigarettes, sunlight, crazing, cracking
Machining and Finishing Data	Drilling: single point or multiple spindle head	Sawing: circle saw band saw jig saw	Contour cutting: pantograph milling mach. router shaper	Finishing: files sander buffer
Available Contours				
Types of Joints				

Induction Hardening Successfully Applied to Large Steel Bearing Races

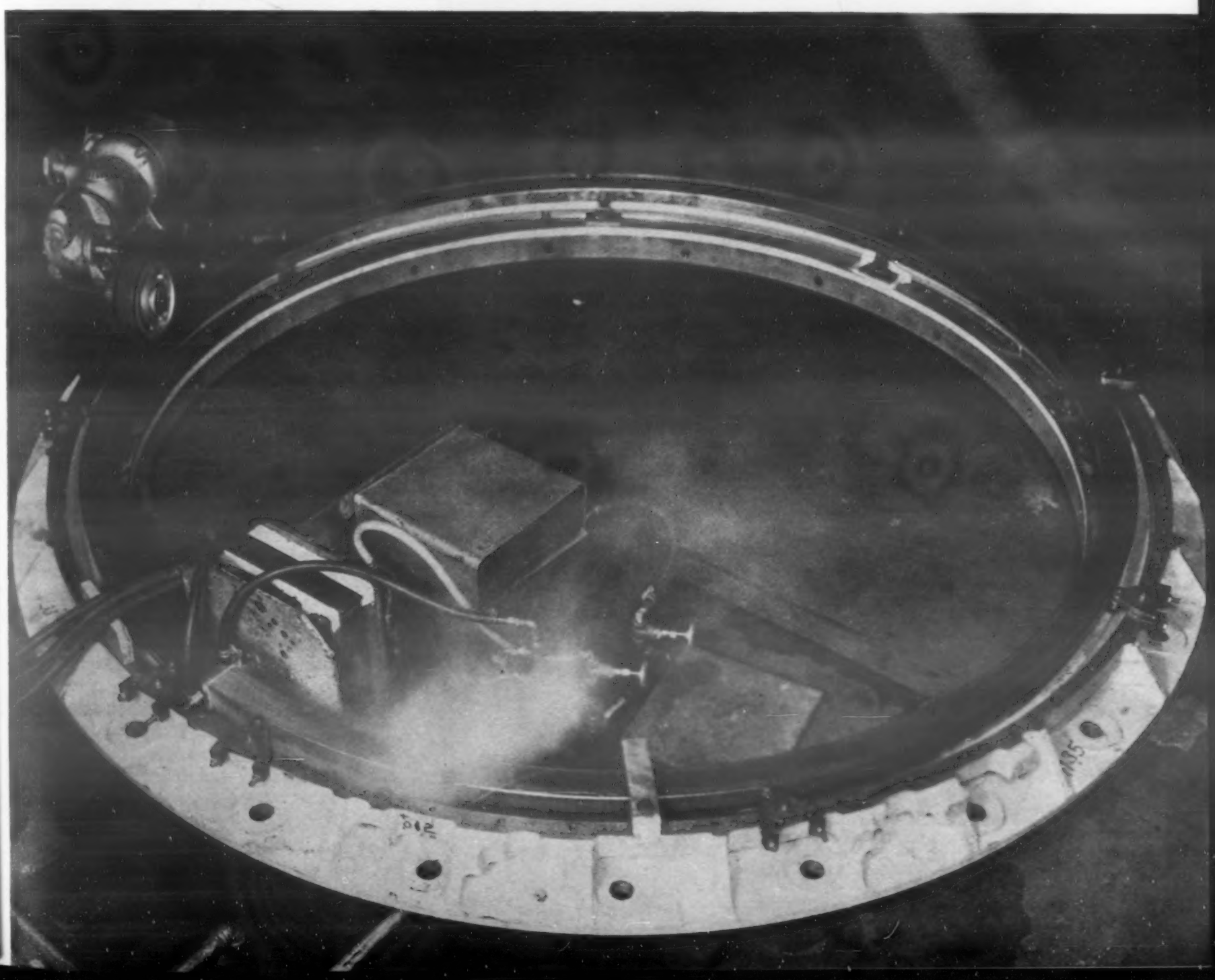
Scale-free, hard-wearing roller path surfaces with practically no distortion were obtained using high-frequency surface hardening.

by **R. H. LAUDERDALE**, Metallurgist, Northern Ordnance Inc.

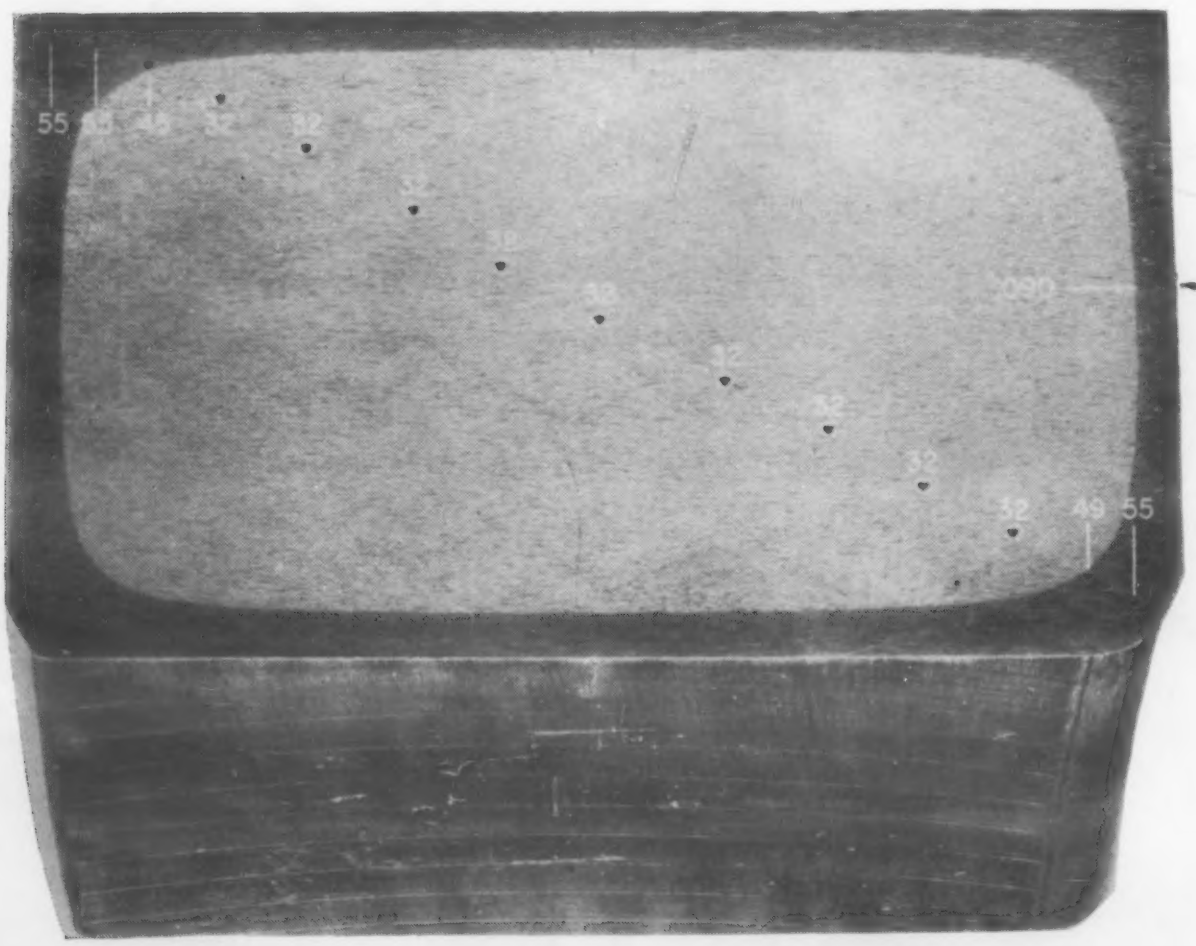
• FOR OPTIMUM PERFORMANCE and service life of large bearing races, it is frequently desirable to obtain a hard bearing surface. However, it has been found difficult and often impractical to harden these large roller paths by conventional methods. For this reason it was decided to determine the feasibility of surface hardening large bearing races by the induction hardening process.

The particular roller paths involved were 82 in. inside dia. with a section 1.5-in. thick by 2.56-in. wide. Previously, an intermediate through hardness of about 32 Rockwell C was specified. However, many of these roller paths showed evidence of "Brinelling" after having been in service. To avoid this in new designs, it was believed advisable to obtain a hard bearing surface of around 60 Rockwell C over a core of intermediate hardness.

Set-up used for hardening bearing races. Roller paths were fed progressively through inductor shown in left foreground.



Location of hardness readings taken at overlap area (above) and on cross section of the roller paths (below).



Several problems had to be studied in determining the feasibility of induction hardening. It was necessary to find out whether distortion or dimensional changes would occur that would require excess stock removal after hardening; the hardness pattern in the overlap area had to be determined; and the danger of hardening cracks had to be investigated. Therefore, six roller paths with known dimensional characteristics were progressively induction surface hardened in various manners.

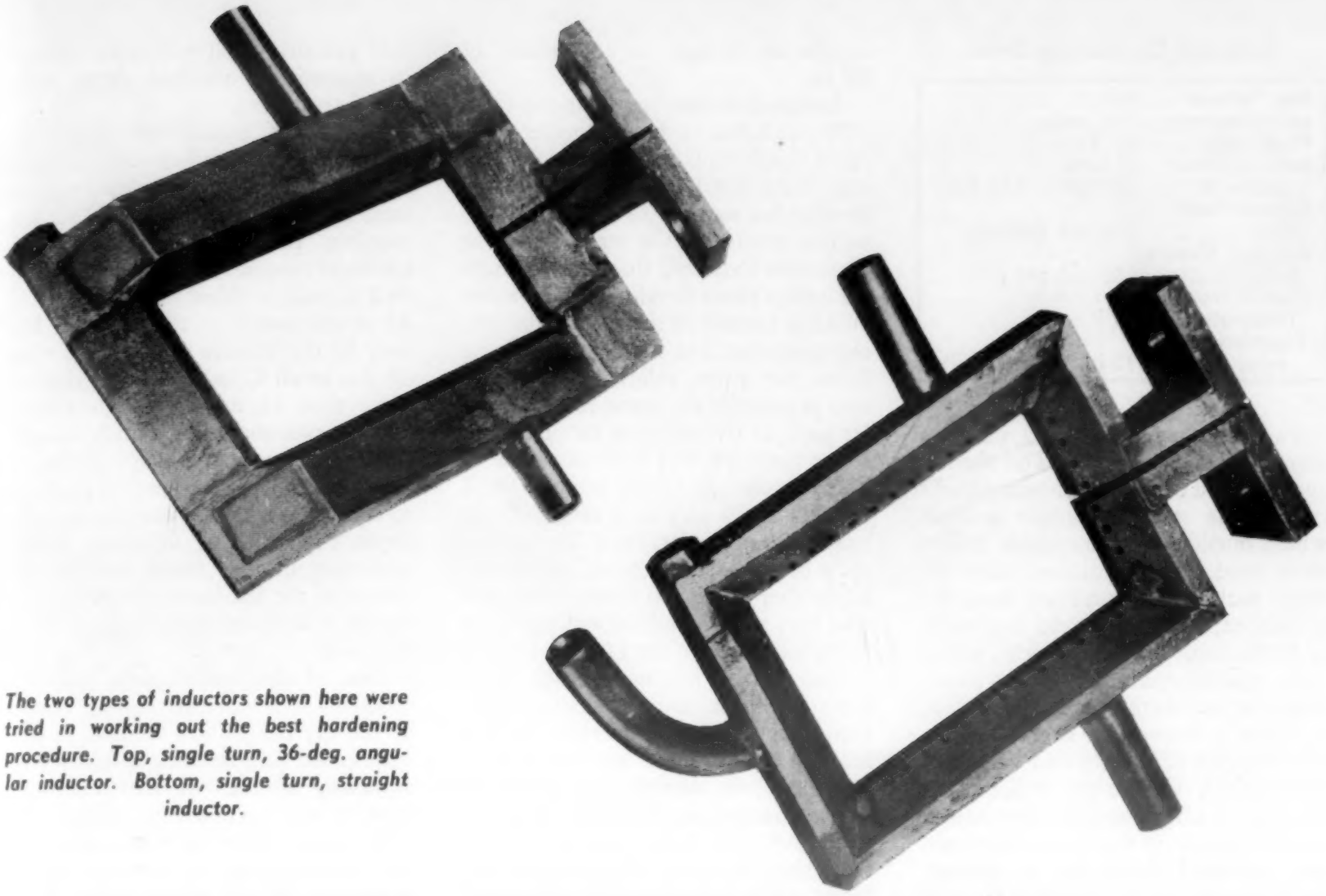
The roller paths used had a smooth chromium plated surface and had been previously through hardened to around 32 Rockwell C. The analysis of the steel was as follows:

Carbon	0.40 to 0.50%
Silicon	0.15 to 0.35%
Manganese	0.50 to 0.80%
Nickel	3.0 to 3.50%
Chromium	1.40 to 1.60%

The high frequency equipment (Tocco) consisted of a 440-v. source of 9600 cycle current, a 14 to 1 ratio step down iron core water cooled transformer, a 230 KVA Pyranol capacitor unit, and a single turn split type copper inductor with integral 36-deg. angular water quench. A constant speed motor driven rubber drive wheel fed the roller paths progressively through the inductor. The roller paths were supported in a horizontal plane by eight needle bearing roller assembly units, and were guided through the inductor by suitable needle bearing guide roller units located on the inside and outside diameters of the roller path at points near the inductor. A secondary or auxiliary water quench was located about 12 in. away from the inductor.

Hardening Procedure

Four roller paths were hardened with a single turn straight inductor and two with a single turn 36-deg. angular inductor (see accompanying photograph). The object of trying the angular inductor (designed to give the same relationship between width of heated band and quench) was to obtain a hardness closure running at an angle across the wearing surface of the roller path instead of radially. Seven guide rollers guided the outside diameter of the roller path and one on either side of the inductor to maintain a clearance of approximately 0.060 in. between the copper inductor and all surfaces of the roller path. The water spray quench hit the heated surface of the roller path in a vertical plane ¼ in. away from the centerline of the inductor and at



The two types of inductors shown here were tried in working out the best hardening procedure. Top, single turn, 36-deg. angular inductor. Bottom, single turn, straight inductor.

36 deg. to the horizontal plane of the roller path. Thus, at any given time during the progressive hardening operation there was a narrow band (¼ in. wide) of red hot surface metal continuously passing under the cold water spray quench.

At a point about 12 in. away from the inductor, a second quench consisting of a low velocity spray of water surrounded the roller path to remove residual heat that might expand the ring and cause binding of the guide rollers on the outside diameter of the roller path. Nevertheless, it was found necessary to set all guide rollers at 0.015-in. clearance to provide for any expansion or out of roundness that might occur during the progressive hardening operation. This method of guiding the roller paths was later replaced by a system of four guide rollers acting on the inside diameter of the roller paths and two guide rollers against the outside diameter on either side of the inductor. This system was necessary to keep the roller paths evenly spaced within the inductor in order to have the water quench strike the roller path surface in a true vertical plane around its periphery. The heating effect from this narrow, close coupled inductor was so intense that any appreciable irregularity in the water spray quench would cause unevenness in hardness and case depth.

Due to the fact that the roller paths had to be quenched down to room temperature to facilitate mechanical handling (appreciable expansion would cause trouble in maintaining working clearances), some of the roller paths were subjected to several low temperature cycles of stress relief to study the effect on both microstructure and dimensional stability. Accordingly, three of the roller paths were placed in a large circular electric furnace and held approximately 1 hr. at 400 F. Dimensions were checked after the roller paths had cooled to room temperature and the cycle was repeated once more. Following the stress relieving treatments, the roller paths were allowed to stand at room temperature for a period of 11 days before final dimensions were checked.

To determine the hardnesses achieved by induction hardening, a section was cut out of one of the rings hardened by use of the single turn straight inductor. This section was cut to include about 1¼ in. of section on either side of the hardness closure. A surface hardness survey was made covering the closure area and also of the roller path cross section. In making the hardness closure, the point where the initial progressive hardening was started was permitted to progress through the inductor to a position even with the midpoint of the inductor, thus assuring the least possible amount of reheating of the previously hardened surface.

Results Obtained

The six roller paths were successfully hardened in one pass; that is, no binding of the guide rollers occurred which required more than one hardness closure per roller path. One of the roller paths hardened with the angular closure and two hardened with the radial closure were given the stress relieving treatment after hardening and were measured for inside diameter taper. The roller paths were not measured for inside diameter taper before hardening, but based on measurements made on similar roller paths not hardened, it was believed safe to assume that no taper existed before induction hardening.

The angular closure method seemed to cause the roller paths to go appreciably out-of-round. In the one case, out-of-roundness increased from 0.0035 in. before hardening to 0.035 in. after hardening. In the second case, out-of-roundness increased from 0.002 in. before hardening to 0.052 in. after hardening. Out-of-roundness caused by the straight or radial type closure ranged from 0.002 to 0.009 in., with an average of 0.007 in.

Effect of induction hardening upon the average inside diameter ranged

General Operating Data

Line Voltage	400 v.
Line Amperage	150 amp.
Power Input	62 kw.
Reactive Power	2 Kvar.
Capacitance	19.2 Mfd, 184 Kva.
Quench Water Flow	3½ gal. per min.
Auxiliary Quench Flow	1½ gal. per min.
Quench Water Temperature	52 F
Progressive Hardening Speed	16 in. per min.

from an increase of 0.009 in. to a shrinkage of 0.0027 in. The shrinkage occurred on the two bearing paths having the straight closure and on which outside diameter guide rollers were used. This indicated that the roller paths were restricted from the normal expansion expected as a result of hardening. The roller paths, which were guided mainly on the inside diameter and therefore essentially free to expand, showed an average diameter increase of 0.0034 and 0.009 in., respectively. Of the two roller paths hardened with the angular closure and guided mainly on the inside diameter, one increased 0.001 in. in average inside diameter and the other showed a shrinkage of 0.0002 in. Both of these last two values represent an insignificant change on a diameter of 82 in.

Inside diameter taper ranged from 0.001 to 0.002 in. for one roller path, from 0.005 to 0.007 in. for another, and from 0.001 to 0.006 in. for the third roller path.

The results of the stress relieving treatment indicated that a rather high shrinkage stress developed in all roller paths as a result of the surface hardening operation. The shrinkage resulting from the stress relieving treatment was practically the same for each roller path so treated even though these roller paths showed various values of diameter change (from minus 0.0002 to plus 0.009 in.) as a result of the hardening operation itself. The second cycle of stress relief caused practically no further change in dimensions; this was also true of additional aging at room temperature for 11 days.

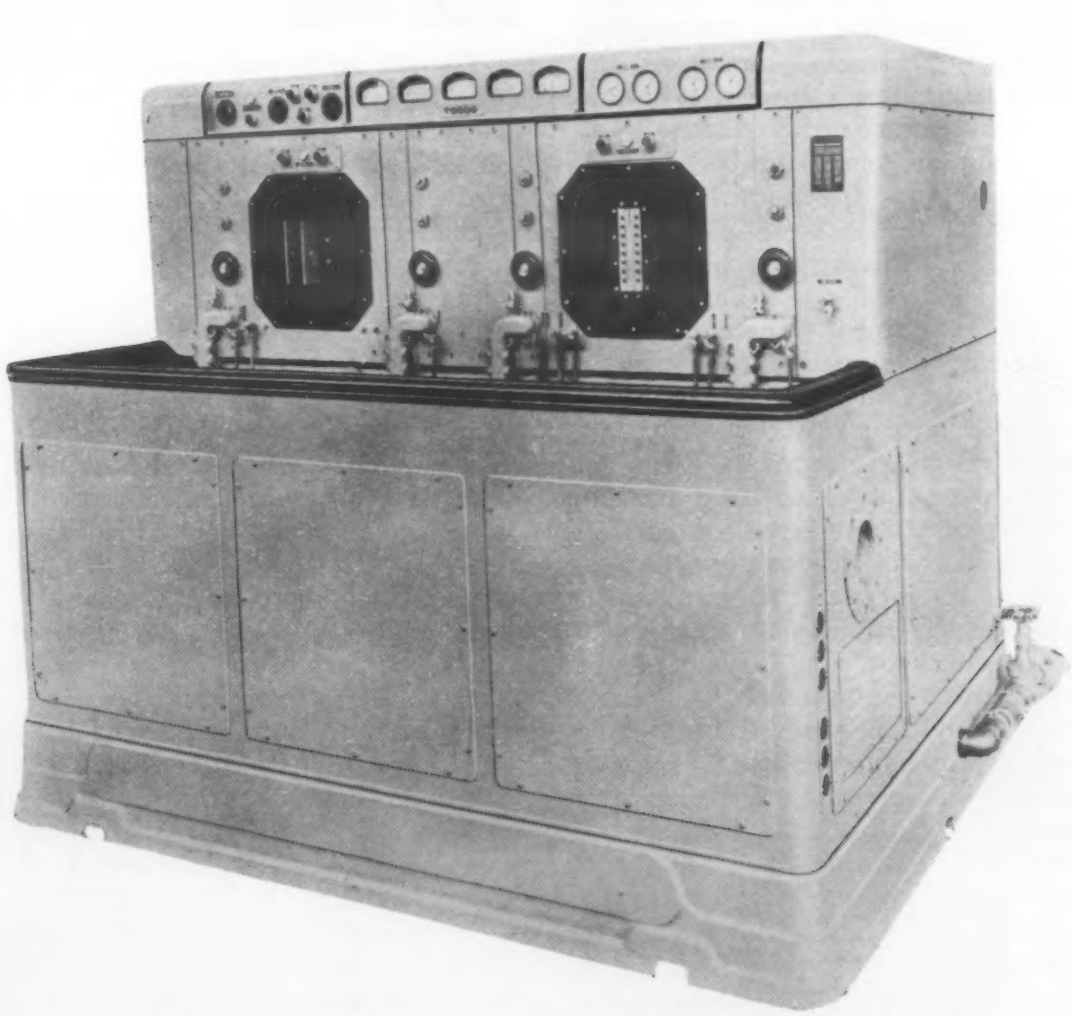
The changes in out-of-roundness as a result of the stress relieving treatment were 0.0045-in. decrease for one roller path, 0.001-in. for the second, and 0.0045-in. decrease for the third. These changes are probably insignificant and may have resulted partly from shop handling. Dimensional stability of the roller paths was obtained essentially from the first stress relieving cycle, as evidenced by the fact that practically no additional change in dimensions resulted from additional treatment.

Rockwell C hardness readings were taken at the overlap or hardness closure section and also across the cross section, as shown in the accompanying photograph. The surface hardness ranged from 58 to 60 Rockwell C with a minimum hardness of 42 at one point in the closure. The area in the closure having less than 58 Rockwell C hardness was slightly more than ¼ in. wide. The etched cross section showed a sharply defined case of approximately 0.090-in. depth. The transition zone from full hardness to core hardness was narrow and the depth of hardening uniform. Slight upsetting of the metal surface occurred at the hardness closure, resulting in a 0.002-in. deep depression at this point.

One of the roller paths was inspected for surface hardening cracks by the dry Magnaflux method. It was anticipated that cracking might occur, especially around the sharp corners, since it was necessary to quench the roller paths down to room temperature immediately to prevent undue expansion of the whole roller path. However, no evidence of cracking could be found. In fact, the roller path Magnafluxed had actually been progressively induction hardened two times with several hardness closures each time and no stress relieving treatment after either hardening. The primary spray quench was so designed as to not impinge directly on the corners of the roller path. This design no doubt aided the prevention of the formation of hardening cracks.

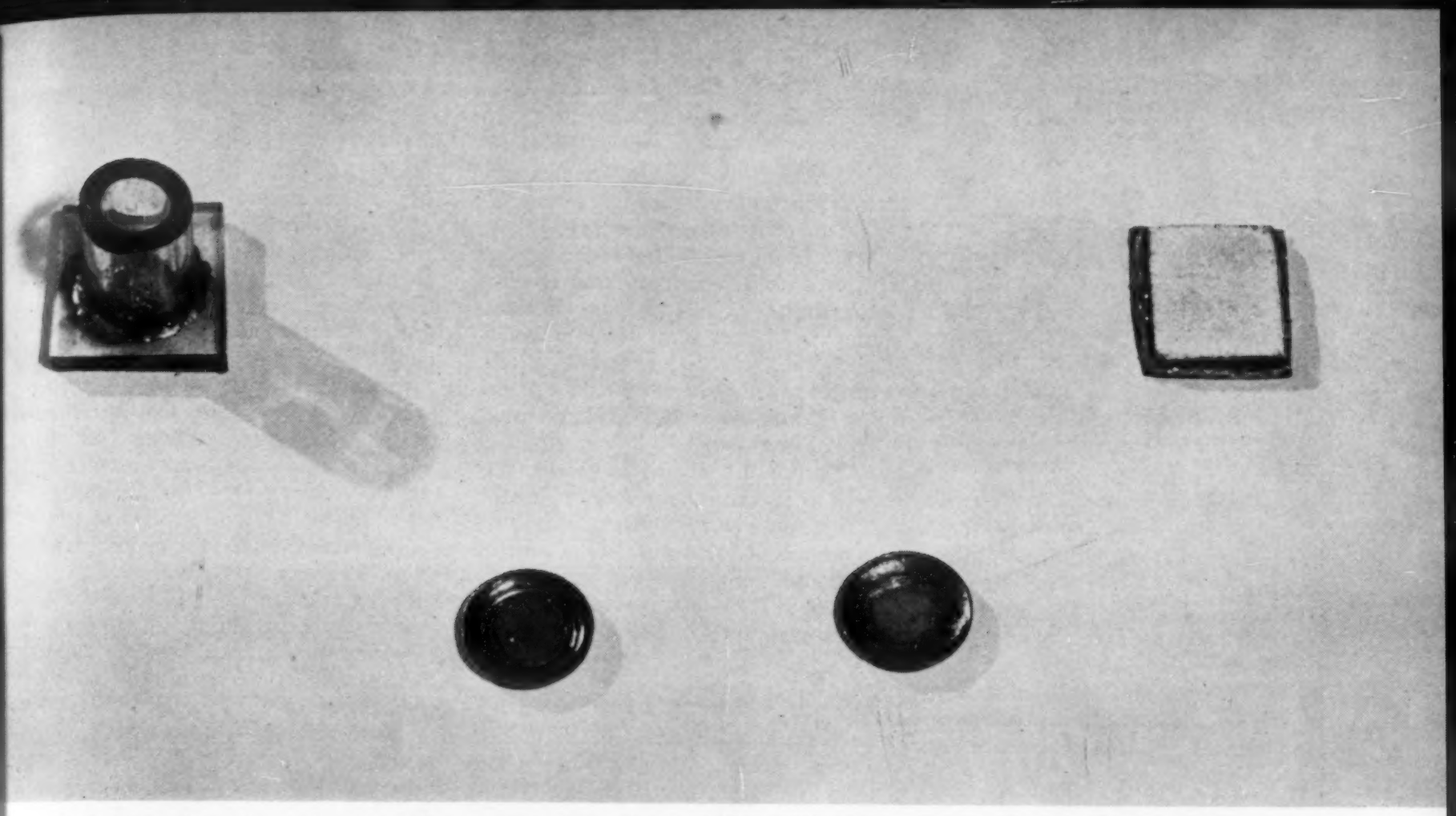
From these studies, it can be concluded then, that progressive induction hardening is a feasible and practical method of obtaining a scale free, hard wearing surface on relatively large roller paths. The amount of distortion or dimensional change resulting from this process is very slight, and a simple low temperature stress relieving treatment performed after induction hardening imparts dimensional stability with little loss in surface hardness. This is a favorable factor, as it is certainly desirable to remove as little stock as possible during grinding following the hardening and stress relieving treatment.

In addition, the hardness pattern at the hardness closure or overlap area is not objectionable from a load distribution or wear standpoint, and there is little if any danger of hardening cracks.



An induction heating unit similar to the type shown here was used in hardening the bearing races. (Courtesy The Ohio Crankshaft Co.)

This work was done under contract with the Navy Dept., Bureau of Ordnance



Typical brazed samples. Left, pyrex tubing to pyrex sheet using lead-silver solder. Center, ceramic to copper-clad stainless steel using silver-zirconium alloy. Right, alundum ceramic to tantalum sheet using pure silver solder and zirconium hydride.

New Brazing Method for Joining Nonmetallic Materials to Metals

by **C. S. PEARSALL**, Research Laboratory of Electronics, Massachusetts Institute of Technology

With this one-step brazing process, ceramics, carbides and other nonmetallics can be joined to each other or to metals giving a strong lasting bond.

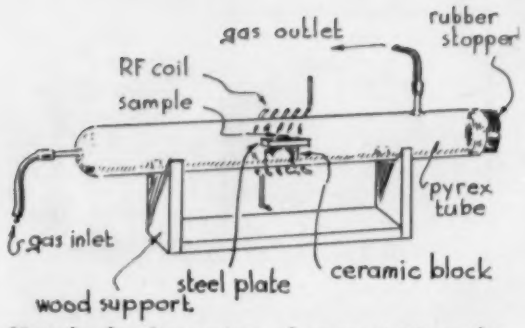
• A NEW METHOD of brazing nonmetallic materials such as ceramics, carbides, sapphires and diamonds to metals has been developed and should find ready application as a method of producing tools and many other products. This brazing process is a one-step operation and is carried out in controlled atmospheres or in vacuum without the use or application of fluxes. It produces an exceptionally strong bond which, in many cases, exceeds the strength of the nonmetallic material.

In developing this process, a series of experiments was carried out with solders in the melting-point range of approximately 390 to 1830 F. The technique developed consists, briefly, of producing a brazing alloy which will wet and bond both metals and nonmetals by either of two means: (1) by the use of certain metal hydrides; or (2) by the use of special brazing alloys.

The Use of Hydrides

The hydrides used include those of titanium, zirconium, tantalum and columbium. The general procedure involves coating the surfaces to be brazed with a thin film of the metallic hydride. A water paste or a nitrocellulose-solution binder seems to work equally well in producing a thin, uniform coating of the hydride. A piece of suitable solder is then placed in contact with the hydride-coated surface, and the material is heated to approximately 1830 F in a vacuum of approximately 10^{-4} mm. of mercury or better, or in an atmosphere of pure hydrogen or a pure (or sometimes commercial) inert gas. When the proper temperature is reached, the brazing alloy will melt and flow over the hydride-coated surfaces in a manner somewhat similar to the brazing of metals.

Zirconium hydride has been found to be superior to titanium hydride in this type of operation. So far, columbium and tantalum hydrides have not proved to have any particular advantages over titanium or zirconium hydrides.



Sketch showing setup of some test equipment used in developing the new brazing method.

Copper-silver eutectic solder (melting point 1435 F) and pure silver (melting point 1760 F) both yield satisfactory bonds. Pure aluminum has also been used as a solder with excellent results. Although the solubility of titanium and zirconium is low in aluminum, the titanium-aluminum and zirconium-aluminum combinations yield good brazing alloys. Pure aluminum gives particularly good results with tantalum and columbium hydrides.

Brazing Alloys

These alloys have been prepared from both the metal hydrides and the pure metals. Zirconium hydride can be heated in vacuum at approximately 1470 to 1830 F to remove the hydrogen, leaving a relatively pure zirconium metal powder. This partially sintered metal powder can be exposed to air and then used in a manner similar to zirconium hydride to produce an equally good braze. In contrast to most zirconium metal powders, this sintered material does not seem to be highly pyrophoric. This would indicate that hydrogen plays no important function in brazing. Apparently the function of the hydride is to yield a relatively pure active metal for the brazing operation.

To verify this assumption, alloys of silver and zirconium were prepared in vacuum. It was found that an alloy containing 15% by weight of zirconium will wet and bond ceramics, diamond, sapphire, carbides, metals, etc. in much the same manner as the hydride method. Equally good results can be obtained by placing pieces of zirconium and silver wire on the surface to be brazed and heating to the flow point as already described. Alloys of aluminum and zirconium, and of aluminum, silver and zirconium have also been prepared. These show good wetting and bonding properties.

Controlled Atmospheres

Zirconium hydride and zirconium alloys are superior to titanium when used in an atmosphere of highly purified nitrogen. With titanium present, the solder flows poorly and exhibits considerable discoloration. Zirconium, on the other hand, has good wetting and bonding qualities and yields a clean bright surface.

Zirconium also has the decided advantage that successful brazing can be carried out in dry commercial tank nitrogen as well as in commercial helium or other inert gases. With these commercial atmospheres a certain amount of tarnish is produced on the brazed surface. Aluminum solders cannot be used in nitrogen due, in all probability, to the formation of the highly refractory nitride.

Brazing in commercial tank hydrogen is not successful with either titanium or zirconium hydride, because commercial tank hydrogen contains sufficient oxygen to convert the hydrides to oxides, thus inhibiting the brazing operation.

Brazing with titanium hydride in pure hydrogen, as described by Bondley,[1] necessitates careful purification of the gas. The resulting brazed joints have a bright yellowish color with pure silver, and they exhibit a slight tarnish after standing in air for a short time. This tarnish apparently forms a protective coating, for no further change has been observed in articles exposed to ordinary laboratory atmosphere for several months.

Both zirconium and titanium exhibit the same behavior when the brazing is carried out in vacuum. As might be expected, both zirconium and titanium hydrides and zirconium alloys yield good results in highly purified argon.

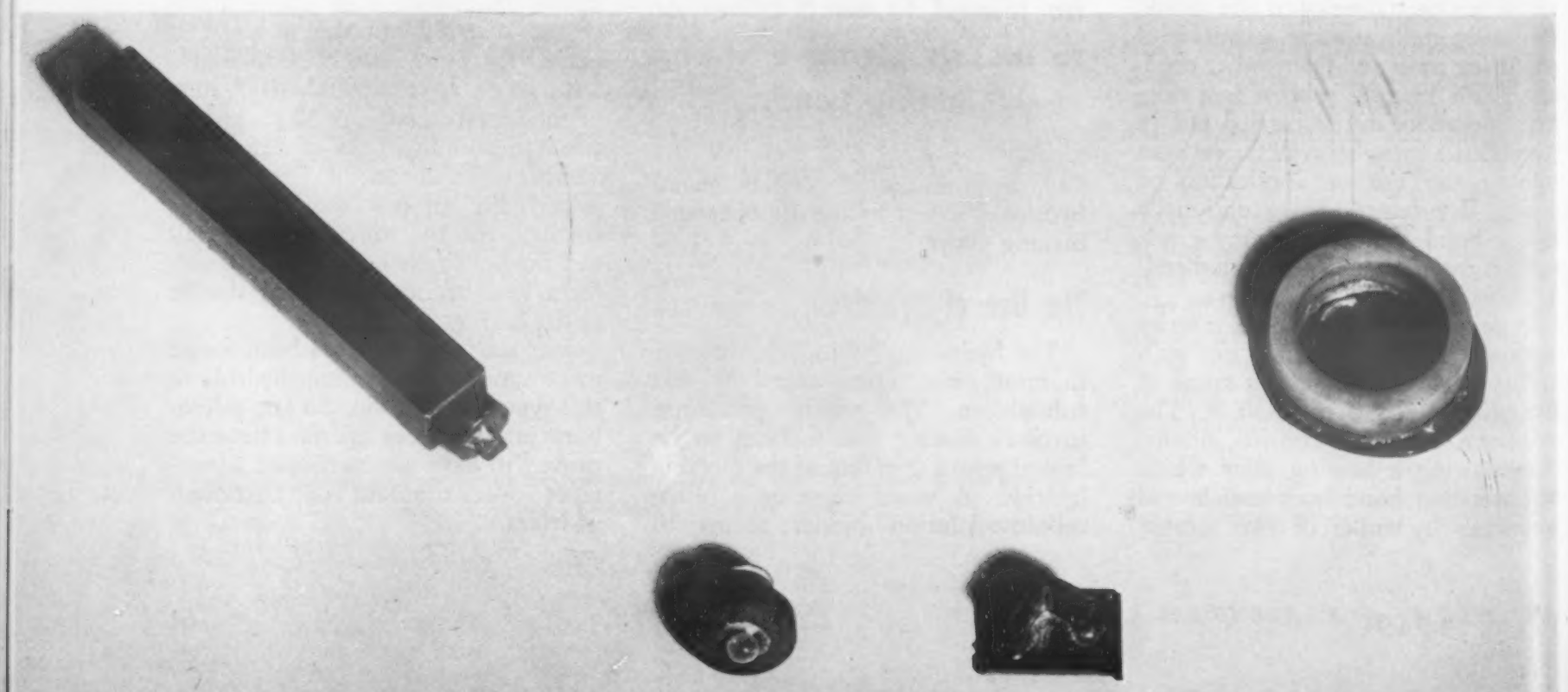
With this new brazing technique using zirconium hydride and zirconium alloys, good brazes have been made to ceramic, diamond, sapphire, carbides, chronium-iron, stainless steel, molybdenum, etc. in an atmosphere of tank nitrogen. Some elementary tools have been made in the laboratory with the zirconium brazing technique. Small diamond cubes have been brazed directly to the ends of steel rods and have been used to cut ceramic tubing in an ordinary lathe. Small synthetic sapphire balls have been prepared in the same manner for burnishing tools. Diamond core cutting drills have been made by brazing diamond powder to steel tubing.

Reference

[1] R. J. Bondley, "High Temperature Metal-Ceramic Brazed Seals", General Electric Research Lab. Research Report, Apr. 1947.

The work described in this article has been supported in part by the Signal Corps, Air Materiel Command and O.N.R.

This method is useful for brazing tool tips. From left to right are shown diamond brazed to steel, sapphire to steel, chromium iron 430 to chromium iron 430, and steatite ceramic to stainless steel.



Aluminum Foil Finds New Uses as a Packaging and Insulating Material

by **KENNETH ROSE**, Western Editor, Materials & Methods

Moisture resistance, light weight, heat and light reflectivity are a few of the many attractive properties of aluminum foil which have expanded its use in both industrial and consumer fields.

Aluminum foil is being widely used for containers such as these shown here being inspected. (Courtesy Reynolds Metals Co.)

• ALUMINUM FOIL is being put to a number of new uses that are taking advantage of its many useful properties. The packaging of food and similar perishable items is providing an important market. Heavy industry also is becoming increasingly package-conscious. Today certain branches, notably the aircraft and the radio industries, are packaging certain types of spare parts in hermetically sealed cans that resemble the food industry's sanitary can in both appearance and method of use. Even where the requirements are not severe enough to demand hermetic sealing, industry has found that more careful attention to the protection of parts in storage or transit is a paying proposition. The automotive industry has found that a wrapping which will provide a reasonably effective moisture barrier pays its way in the packaging of small parts.

The increasing availability of a high-grade aluminum foil has also encouraged its use in fields other than packaging. It is now a standard heat insulator. Certain uses in fire protection are being considered. Its excellent light reflectivity is another property now being utilized.

Properties and Advantages

The most important of the properties that give aluminum foil its wide and growing acceptance are:

(1) It serves as an excellent moisture barrier. The foil is a continuous and impervious film of metal, so that even in light weights it gives protection to food products and to industrial goods.

(2) Heat transmission is excellent. Partly because of the high coefficient of heat transfer in aluminum, and partly because of the thin film used, heat transfer through the foil is rapid. One of the large-scale users of aluminum foil for packaging has been the frozen food industry. The high rate of heat transfer is important not only in the freezing of the food, but permits it to be warmed quickly when ready for use.

(3) It is noncombustible. In the food packaging field this makes it possible to remove the packaged food from a refrigerator and place the food, still in the package, directly into the oven. The foil container may be placed upon a heating unit directly, if due regard be given to the mechanical strength of the thin metal. This property of noncombustibility is also of importance in the use of foil as a heat insulator.

(4) It possesses high resistance to oxidation. The aluminum foil is not subject to the weakening that results from corrosion of many other metals. Corrosion would also affect the flavor of food packaged in such containers.

(5) The material is light in weight.

This is the result not only of the low specific gravity of the metal itself, but of the thin sheets into which the material is rolled. The saving in shipping and handling costs is considerable.

(6) Reflectivity for both heat and light is high. This reflectivity is the basis for use of the foil as a heat insulator, in spite of its good heat conductivity.

(7) Aluminum foil is nontoxic. It can be used in direct contact with most foods without special treatment of the metal, such as bonderizing or lacquering.

(8) The surface takes printing well. This makes it possible to print identifying labels directly on the foil, instead of pasting on a label.

(9) Cost is low. On a volume basis aluminum is a low-cost metal, and some of the thin foils are priced competitively with paper.

(10) It possesses an attractive, metallic appearance. The bright luster and the silvery whiteness of the metal have given it a use even where its other properties are not needed, as in the use of thin printed foils, paper backed, for labels on bottles and cans.

Heat Insulation Uses

Aluminum foil has been found to serve well as a heat insulator in domestic ranges. Here the material is used as loosely crumpled balls of the thin metal placed between the inner and outer walls of the stove. The lustrous surface of the foil reflects the radiant heat back toward its source, while the crumpled form of the material provides dead air space to reduce losses by convection and conduction. Several additional features of the aluminum foil insulation are (a) its extremely light weight, (b) its ready adaptation to difficultly accessible interwalls, and (c) its low-cost and labor-saving means of installation.

The same idea of heat insulation by high reflectivity is utilized in a new fire-fighting suit now under test by the U. S. Air Force. The suit is intended to be worn by men of the crash squads for approaching burning aircraft, and must withstand high degrees of heat, though it is not intended to be worn into the flames. The material of which the suit is made is a cotton-backed aluminum foil, and the suit itself consists of trousers, zippered jacket, gauntlets, zippered spats, and a rigid helmet. A new model of the suit will use a backing of glass fiber, and the suit will be sewn with thread of glass fibers. The weight of the entire suit is about 8 lb. The suit gave better protection and suffered less damage in tests than the present standard suit.

Packaging Applications

Recent developments in the packaging field are among the most interesting, and promise the widest market for aluminum foil. One of these is the ingenious combination of package and tray that is already in use by several food product manufacturers. It is a shallow tray or box made by folding a sheet of aluminum foil so that it will be liquid-tight without soldering or otherwise heat-sealing. The open seams are brought to the top of the tray by the folding, and a lid, also of aluminum foil, can be placed over the top by simple bending or by crimping. The lid does not form a liquid-tight seal, however.

This container is of a type that stands midway between the ordinary foil wrapping and the sanitary can in its field of use. It is not rigid and suitable for hermetic sealing, as is the sanitary can, and is not intended for packing and transporting sterilized foods. It has the advantage over the foil wrapping, however, of being capable of holding, in a definite shape, both solid and semi-solid materials. Semi-solid materials will include those that can be poured into the trays as hot liquids, and will set up to jellylike consistency upon cooling.

The foil is 0.004 in. thick, and is made of pure aluminum. The folding of the foil to produce the tray means that there is no organic binder at the seams, thus avoiding use of a material that would deteriorate under heat. The weight of the trays, only about 25 lb. per 1000 in the pint size, is slightly increased (to 37 lb.) by addition of the aluminum foil tops. As the trays nest to a compact stack when empty for easy shipping or storage, they have an advantage here over the sanitary can. Although the tray is not considered a rigid container, it is surprisingly stiff. The empty foil container with sealed foil lid will withstand compression in excess of 35 lb. The lid can be labeled, or the subject matter of the label can be printed directly onto the lid itself.

A Midwestern food manufacturer is now using the tray to package, ship and sell foods that set up to semi-solid form after cooling. The package is intended to be placed directly into the oven by the user, warmed, and served. Although the tray is quite durable, the difficulty of accomplishing a completely satisfactory cleaning of the folded foil after use has resulted in its being offered as a one-trip package. Its low cost makes this feasible.

Packaging of spare parts is an important application of aluminum foil. Here a bearing is wrapped in foil laminated to paper. (Courtesy Aluminum Co. of America)

A promising field for aluminum foil is in the self-service stores for prepackaged foods. Another use in the food-dispensing industry is for heat-conserving covers on coffee or soup containers, especially for curb service. A thicker foil, about 0.007 in., is used. Users report a noticeable improvement in heat-retention due to the aluminum reflecting heat back into the container.

Aluminum milk bottle caps are now a standard item. In addition to being easy to apply, the metal caps can be completely sterilized by heat, and impart no taste to the milk.

Foil Laminates

Another active line with wide applications is the aluminum foil laminate. For some of the uses, the aluminum foil is added for its attractive appearance only, while in other cases it is the major part of the composite, with a paper or plastic backing added for increased resistance to pinholing. The range of applications runs from attractive labeling of beer bottles to moistureproof packing of aircraft and radio parts.

In the decorative bracket is the use of very light foils, about 0.00035 to

Insulating a freezer with fiberglas over which aluminum foil is placed. In the foreground, foil has already been placed around three sides. (Courtesy Nash-Kelvinator Corp.)

Aluminum foil has proved itself to be an excellent insulating material. (Courtesy Aluminum Co. of America)

0.0004 in. thick, for attractive labeling and packaging. Canned food, packaged dried fruit, bottled beer and other beverages, toiletries, etc., are making use of the thin aluminum layer, backed by paper, for sales-promoting labels. The paper backing makes possible the use of a thinner foil than would otherwise be practicable, and also simplifies the matter of bonding to the container. The principal features of aluminum for this use are its high luster and silver-white color, its excellent printability, and its resistance to tarnishing. By use of transparent and opaque inks over the foil beautiful effects in all colors can be obtained.

The foil-laminated label has an added advantage for labeling beer and soft-drink bottles. As much of the total quantity of such beverages is sold from water coolers, the resistance of the aluminum foil to passage of moisture helps to keep the labels from being washed from the bottles while in storage.

The greatest advantage of aluminum foil in laminated wrappings is its imperviousness to water vapor. Sealed-in water helps to increase the shelf life of dried fruits, candies, certain types of toiletries, etc., by preventing these products from drying out between the time of packing and the time of sale. Laminations use foil of about 0.0002 to 0.0004 in. thick, with paper to give bulk, strength, and a degree of stiffness. When the vapor barrier must be unusually good, an interlayer of wax will reduce the danger of rupture of the barrier through pinholing of the foil. For wrapping of industrial goods, the intention is usually to keep out moisture and so to lessen danger of corrosion. Aluminum foil is used in a slightly heavier weight, and the backing is ordinarily a kraft paper. A crinkled paper can be used to give additional cushioning against impact, and the foil can be used on one or both sides of the paper. Certain foodstuffs that tend to absorb moisture also use foil laminates to exclude water vapor.

These foils, both for food products and for durable goods, can be obtained in heat-sealing types, in which a fusible plastic or a wax can be easily melted to complete a moisture-tight seal. Contact with a heated iron makes the seal, requiring only a fraction of a second. The wax can be placed between the foil and paper layers in a thin film, localized at the points that will be sealed, and so avoid contact of foodstuffs with the wax itself.

The foil laminates are now being produced in rolls, printed with the label design of the user, and ready for packing and sealing in automatic packaging machinery. In this way the entire operation of weighing or counting the articles being packed into a container, sealing and labeling the container, and, frequently, of packing the individual containers into a shipping carton is completed by one machine. The user merely starts a roll of preprinted laminated foil into the machine, feeds in the product being packaged, and receives the product measured into a metallized container, hermetically sealed if desired, attractively labeled and ready for sale.

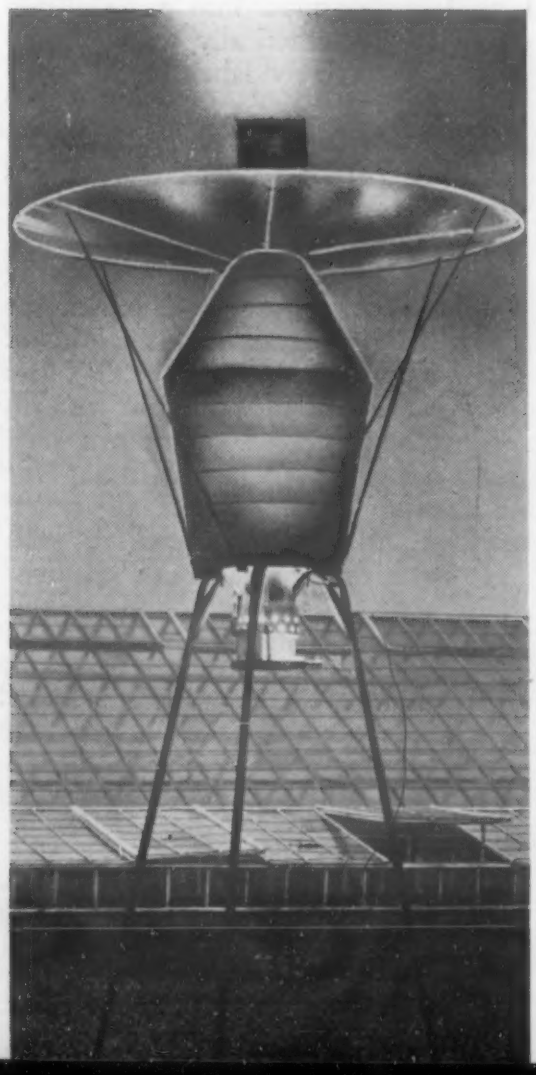
The advantage in shipping highly finished parts in such circumstances that they will be ready for use without cleaning off a layer of heavy grease, and will arrive without any corroding of the surfaces, was learned during the war. A large part of the foil laminates now used for packaging goods other than foodstuffs is applied to packaging military items. The cost of such packaging is higher than that for wrappings or containers of other, more familiar, barrier materials, such as asphalt-impregnated or asphalt-laminated kraft paper. The foil laminate has made gains in the packaging of aircraft repair parts and radio parts, however, and seems to be finding some use in the automotive industry for protecting highly machined pieces during shipment.

Materials at Work

Here is materials engineering in action . . .
New materials in their intended uses . . .
Older, basic materials in new applications . . .

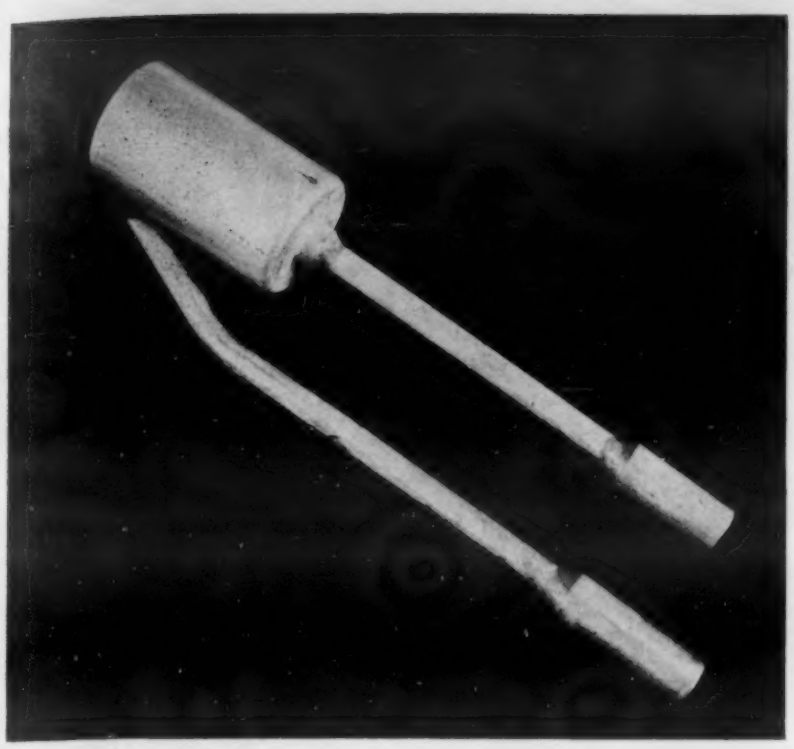
STEEL BETATRON MAGNET CORE

Approximately 44,000 steel sheets, each 0.014 in. thick, were used in the construction of the 160-ton magnet of a 100-million electron volt betatron recently completed for the University of Chicago by General Electric. Forty slabs comprised the magnet core. The larger slabs measured 7¼ by 180 by 39 in. and contained 1700 sheets; the small end slabs, 7¼ by 39 by 22 in., contained about 500 sheets each. Before assembling the magnet core, all contact surfaces were machined to a tolerance of 0.01 in. and, in the case of the top and bottom yoke pieces, this tolerance was maintained over an area 15 by 7 ft. The burrs were removed by nitric acid etching.

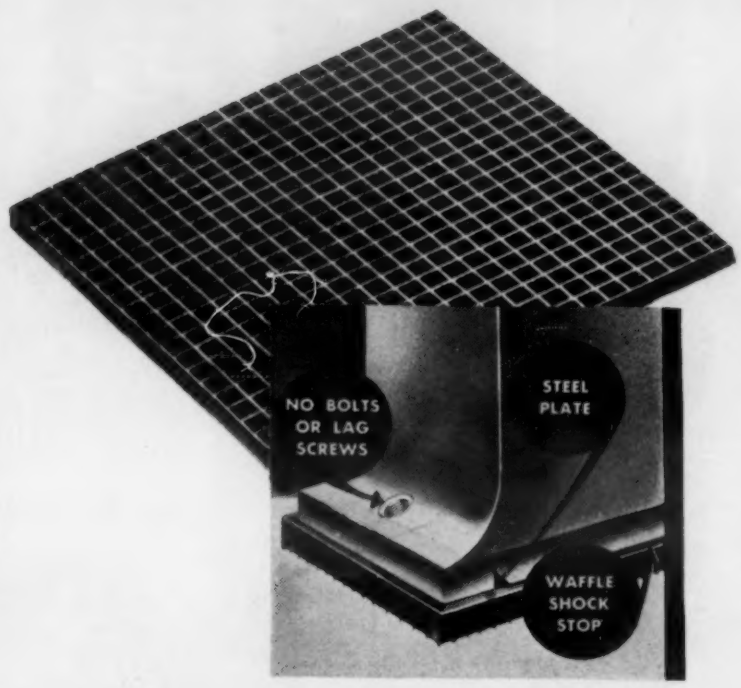


STAINLESS STEEL ORCHARD HEATER

To protect plants and fruit trees from the killing effects of frost, this outdoor heating unit, manufactured by the Evans Products Co., generates infra-red rays to compensate for loss of heat from the earth due to radiation. The heat energy generated is not wasted by loss in the air through which it passes, but travels in waves until it strikes the plants, trees, or other objects to be warmed. Essentially, the device consists of a generator-type burner, a combustion chamber, and a canopy-type reflector. A battery-powered pump supplies kerosene to the burner. Exterior surfaces reach temperatures in excess of 1500 F, and rays radiating from the red-hot surface, plus the rays reflected by the canopy, blanket a considerable surrounding area. The base and flame spreader in the combustion chamber are made of 2 nickel-1% chromium cast iron which provides good resistance to sealing, distortion, and other effects caused by exposure to elevated temperatures. The stack, top shell and bottom shell are fabricated from "18:8" chromium-nickel stainless steel sheet; the baffle and its supports are made from "25-12" (AISI Type 309) stainless.



BRAZING ALUMINUM *Displacing a manual brazing operation, a special-purpose automatic gas-fired machine produced by Selas Corporation of America successfully brazed three different gages of tubular aluminum with only a 50 deg. temperature differential between the flow-point of the brazing alloy and the burning point of the components. The production rate was 500 assemblies per hour. The two-stage machine utilizes sixteen soft-flame gas burners, each controlled for heat input and placed to give the required brazing-heat patterns. Water cooling is used in the first stage. A variable speed control is synchronized with the time heat requirements of the operations.*



RUBBER VIBRATION DAMPENER *Effectively reducing noise and damping out vibrations resulting from motorized equipment, these rubber mountings provide a semi-pneumatic cushion for weights up to one ton for each machine foot. The waffle grid design, when placed under pressure on a smooth surface, traps air in each of the small, square cells. Vibrations are diverted by this air through the vertical ribs and are prevented from passing to the supporting surface. Produced by the Connecticut Hard Rubber Co., these units are claimed to reduce vibrations from 75 to 90% where disturbing frequencies run between 1000 and 3000 cycles per min.*

GLASS FIBER-REINFORCED VAPORIZER *Designed to withstand heat, water, electricity and medications, this steam vaporizer is produced by the Sparton Co. of Minneapolis, Minn. The half-gallon water reservoir is low-pressure molded of Laminac resins, supplied by the American Cyanamid Co., reinforced with Owens-Corning Fiberglas. Metal could not be used for this reservoir without expensive insulation because of the electrical charge transmitted through the water when the unit is in operation. Porcelain and glass would be too heavy, cumbersome and fragile. The use of reinforced plastic successfully overcomes the problems posed by these other materials and results in a lightweight, colorful, and extremely durable unit. An aluminum cover completes the product. Steam is produced in 90 sec., and the vaporizer will operate continuously for 7 or 8 hr., automatically shutting off when the water level gets low.*

RUBBER-COVERED STEEL CONTAINER *A closed-type unbreakable container for use in handling acids, alkalis and other corrosive solutions, this unit is constructed of perforated sheet steel that is completely covered on both sides with a ⅛-in. layer of tough, seamless rubber. The perforated metal is "sandwiched" between the rubber, the layers being joined through the perforations to achieve permanent adherence and to prevent any metal from being exposed. Manufactured by the Automotive Rubber Co., this unit is designed for safe, splash-proof transportation.*

The infra-red drying tunnel in operation. It is 8½ ft. high and 106 ft. long.

Production Drying of Finishes Accomplished with Infra-Red Ovens

Baking enamels are cured rapidly and with high quality results at Studebaker Corp. using radiant heating and closely controlled drying procedures.

by J. A. MARTIN, Plant Layout Engineer, The Studebaker Corp.

● BOTH SPEED AND HIGH QUALITY results are required in the drying of automobile body finishes. Studebaker Corp. has found that these requirements are met with infra-red drying, using lamp banks in a tunnel as the source of radiation. Infra-red lamping permits close control of heat distribution over the entire surface of the work and throughout the entire time of drying. Studies of costs have shown that the method is economical in operation as well.

Baking enamels are now quite generally used throughout the entire automobile industry for original coating of bodies. While the early nitrocellulose lacquers were a considerable improvement over the oil paints, they gave way rapidly to the baking enamels, which show even higher durability and resistance to chalking than the nitrocellulose lacquers.

Baking enamels dry by evaporating the volatile solvent and polymerizing the synthetic resins in the enamel. This polymerization is speeded by applying heat to the freshly painted surface. Suppliers of the enamels can formulate the finishes so as to control, within limits, the temperature at which the coating will set up best. Lower temperatures mean longer drying times, so every user is concerned with drying these coatings at the highest temperature that will give a properly baked finish.

When baking an enamel at the highest temperature that the material

will permit, proper heat distribution is of utmost importance. Temperatures are near the point at which the enamel will scorch, so that any local overheating will result in damage to the finish.

Drying on cab bodies was formerly done by convection in a steam-heated tunnel. The tunnel was 125 ft. long, with two parallel lines. Baking time was 1 hr., and production with the tunnel was 30 pcs. per hr. With the present drying by radiant heat, the tunnel is 106 ft. long, with only a single line, and baking time is 15 to 16 min., with a production of 42 pcs. per hr.

More than one-half of the floor space needed for the convection tunnel has been saved by the present installation. There is a considerable saving in the amount of air used in the drying operation, all of which is washed and conditioned before circulating through the tunnel. Upkeep is lower for the radiant heat tunnel. There are also savings in labor; the convection oven had to be started at 5 a.m. to be operating at 7 a.m. In addition, an improvement in the quality of the work is reported from the paint department, with better flowout of the enamel, and better luster and durability. Against this must be charged an increased cost of energy.

Description of Equipment

The infra-red drying tunnel at Studebaker is a product of the Fostoria Pressed Steel Co. It is 8 ft., 6¾ in. high and 106 ft. long, and contains 2552 lamps mounted in 22 horizontal banks, and divided into 15 sections longitudinally. The lamps are of the carbon filament type, with external gold-plated reflectors. They are mounted on 11-in. centers in both directions. The external reflector has been chosen for this oven as giving a more diffused radiation than the lamp with internal reflector. The gold reflectors will not tarnish, but they may be dulled by dust collected during shutdown, or by the fumes from the coating. Periodic cleaning, once every two weeks, is a necessary part of the maintenance of the lamps.

Electrical energy is supplied from a 440-v. line, using 110-v. lamps connected in series of four. Using the 440-v. line reduces the load on the lighting transformers and provides power at a lower cost.

The lamps are used in 125-, 250-, 375- and 500-watt sizes, giving a flexibility to the energy input at all points in the tunnel through the opportunity to substitute one size for another. Even greater flexibility is given the system by putting lamps on half voltage at points where the temperature becomes unduly high. This is accomplished by using eight lamps in series instead of four, taking care that the eight are all of the same wattage. On half voltage the lamps will give about 25% of the rated energy output. Where the amount of heat must be still further reduced, one or more lamps can be removed entirely.

Although drying is done by radiant heat and convection is held to a minimum, it is necessary to have a small amount of circulating air to carry off the evaporated solvent. Cool air is filtered into the bottom of the tunnel through flat ducts, and passes up through the lamp banks, cooling them, and helping to keep them clean by keeping fumes away from them. About 2000 c.f.m. of air is passed through the tunnel, and all of this air is first washed, brought to about 74 F, and humidified or dehumidified to about 35% relative humidity.

Drying Procedure

In setting up the tunnel for drying operations on an automobile body—in this case the truck cab—the following procedure is used:

1st step—a calculation of theoretical energy input is made.

2nd step—the tunnel is set up to supply the calculated amount of energy, using the practical experience of the men to fix a tentative distribution of heat.

3rd step—a trial run is made with a cab to which thermocouples are attached, and all temperatures are recorded.

4th step—the lamps and voltages are then readjusted to correct any underheating or overheating shown by the trial run.

The enamel used will dry at 280 F within about 10 min., and allowing for about 10 F fluctuation either way, this is a practical maximum. Red, the most critical color, will discolor at about 300 F. The problem, then, is to raise the temperature of the cab, with its pick-up box and truck, from room temperature to 280 F, and to maintain it at that temperature for about 10 min.

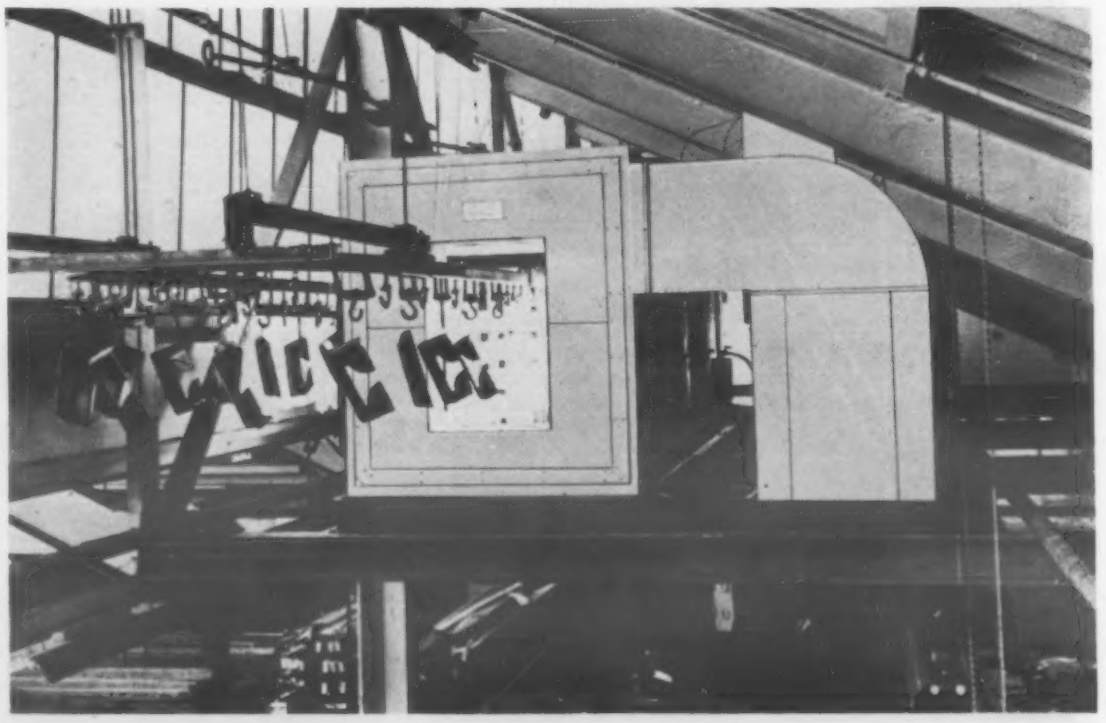
The preliminary calculation is as follows:

> Total wt. of steel x specific heat of steel x no. pieces per hr. x efficiency x factor for conversion to kw. = Theoretical energy input in kw.

In planning the heat distribution, practical experience has shown that the steel should be heated to at least 250 F during the first 4 or 5 min. in the tunnel. This will allow for about 11 min. to bake at temperature. The heaviest lamping will be done during this first period, at the entering sections of the tunnel, and only 125-watt lamps will be required after that. At any cross-section of the tunnel, the heaviest lamping must be in the lower banks, partly because heat will rise with any convection that may occur, and partly because the heaviest metal is in the lower part of the cab.

Experience has shown also that there are four critical points on the cabs as they go through the drying tunnel. These are: (1) the center of the door, (2) the upper door pillar,

Infra-red drying is also used on relatively small parts as shown here. (Courtesy Trumbull Electric Manufacturing Co.)



(3) the center of the back panel, and (4) the center of the top panel. These are the points most likely to be overheated or underheated. In making the trial run each of these points has a thermocouple attached to it to read the metal temperature at that point. These temperatures are recorded each minute during the trial run, and from these data the lamping can be adjusted to secure the best distribution of heat. A trial run sheet is shown in the table included here. A plot of these test results is also given in the accompanying chart, showing the maximum and minimum of the recorded temperatures at the end of each minute during the run.

The lamps are mounted in the tunnel so as to give the closest spacing to the work. The irregular nature of the cab makes this spacing about 10 to 18 in. The energy input is about 3 kw. per lineal ft. of oven.

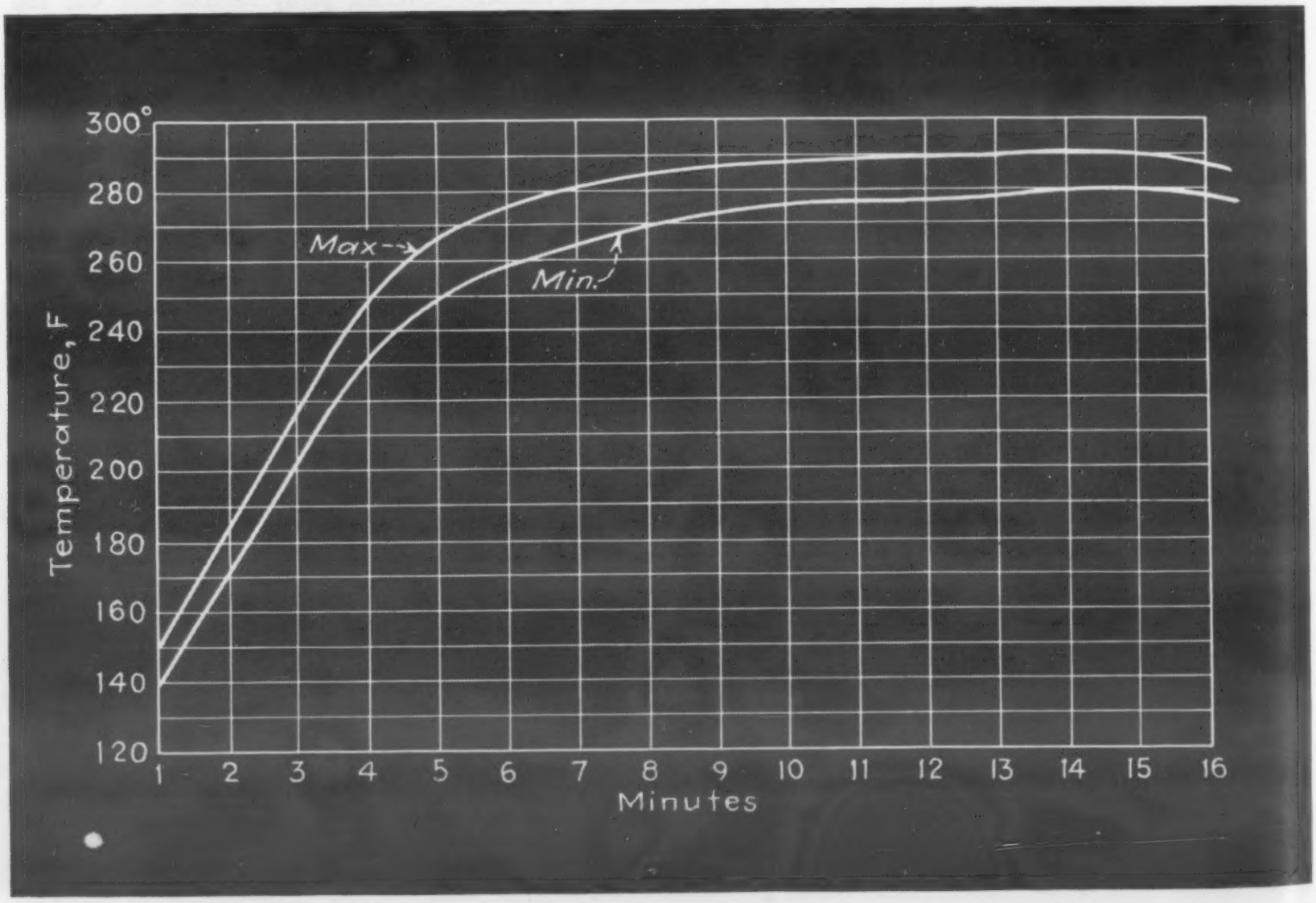
As the cabs leave the drying tunnel they are at the final temperature, about 280 F. The next operations are fitting and trimming. In order to speed cooling to room temperature so that the workmen can touch the cabs, a cooling tunnel is placed at the exit end of the infra-red tunnel. Here the cabs are held in a strong current of air from fans, and after about 2 min. they proceed to the fitting station.

Special switches are used in the electrical connections to guard against improper baking of the finish in the event of a shutdown of short duration in the production line. Originally there was a simple safety swich that shut off the lamps when the conveyor stopped, thus preventing overbaking of some of the pieces. A difficulty with this was that the baking schedule could not be restored for those pieces in the tunnel. There are now two sets of timers, the first acting to delay the shutting off of the lamps for 2 min., and keeping them at full voltage for that length of time. If any minor mishap along the production line, such as a jammed spray gun, causes a short stoppage of the conveyor the second switch operates to keep the lamps lighted for the fixed period, and at the end of that time the second switch shuts off the lamps. The work will not be overheated by standing under the lamps at full voltage for this short period.

Metal Temperature of Cab Parts Processed in Infra-Red Oven

Time, in Min.	Temperature, F			
	Center Door	Upper Door Pillar	Center Back Panel	Center Top Panel
1	150	142	144	138
2	182	175	178	167
3	218	205	215	197
4	249	239	247	237
5	257	252	268	248
6	266	261	275	259
7	269	271	281	265
8	272	275	285	271
9	277	281	287	275
10	277	280	287	278
11	276	283	288	279
12	278	285	290	282
13	278	287	289	283
14	280	289	290	285
15	282	291	291	285
16	278	286	287	278

Time-temperature chart showing maximum and minimum baking cycle for drying enamels on the truck cab.



Materials & Methods Manual

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This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and application

Mechanical Fasteners

—Their Selection and Use

by N. Bruce Bagger, Associate Editor, Materials & Methods

There are many different types and styles of fastening devices that can be used for joining materials. But the choice and use of any one of these devices is conditioned by the end-requirements of the given application for which it is intended. It is only through a careful and intelligent analysis of these requirements that the selection of a satisfactory fastener can be made. Six basic categories of permanent and semi-permanent fastening devices are discussed, not from the standpoint of the actual installation techniques involved, but from the relative behavior they, and the materials from which they are made, exhibit for fastening applications.

Contents

Introduction

Since man first affixed a sharpened stone to a stick with rawhide, fasteners and fastening devices have played a major role in his daily life. Today, our civilization is literally held together with fasteners; transportation, communication, housing, production, and distribution are all dependent upon various kinds of fastening devices for their successful operation.

Some of the fasteners in current use are comparatively new, and employ techniques unthought of a generation ago; others extend back thousands of years, and although now greatly improved and refined, are still basically the same as their age-old antecedents.

The variety of fasteners and fastening techniques in use today is exceeded only perhaps by the myriad uses to which they are applied. Certain types of fastenings have limited application, their use being restricted to the joining of specific materials of a given shape and size or for given service conditions. Other kinds often can be applied irrespective of these limitations. The entire field of fastenings ranges from headed and threaded permanent or semi-permanent types to the totally permanent joints obtained by welding, brazing, soldering, and the like. Because of the obviously broad scope of the field, this presentation is limited to the headed and threaded types and the adjunctive accessories that contribute to their fastening efficiency. However, the distinctions that exist between the various groups are not entirely inflexible, and some overlapping does occur. This is particularly true in cases where standard threaded fasteners are readily utilized for such applications as enclosures, access plates, covers, lids, etc., which are normally secured by the so-called "patented," semi-permanent, cam-action fasteners. But despite this and other instances where two or more different types of fasteners can be applied to a particular joining problem, there are certain broad definitives that effectively group most fastening devices. The satisfactory choice of a fastener from one of these groups depends in a large measure upon a knowledge of the advantages and limitations of the fastener itself, a knowledge of the materials from which the fastener is made, and a knowledge of the service conditions to which the fastener will be exposed.

Bolts and Screws

Bolts and screws are perhaps the oldest fastening devices known. Together with nuts, they comprise the largest group of related fasteners in use today, and their applications extend to virtually all manufactured products.

Bolts and screws are commonly produced in three degrees of finish. Unfinished units are hot forged and not machined on any surface other than the point and the thread. Semi-finished bolts and screws are faced or otherwise machined under the head to a bearing surface with a washer face. Finished units are machined on all surfaces and the bearing surface under the head is washer-faced.

The threads are the most important part of both screws and bolts alike, as it is through these that the fastening action is obtained. Threads are usually formed in three general ways: Rolling, cutting, or extruding and rolling. Of the three, greater strength is usually attributed to the rolled type, since the cold-working caused by the rolling, and particularly by extruding and rolling, increases the tensile strength of the screw or bolt. However, this increase in tensile strength is often dissipated in cases where subsequent heat treatment is required, so that the strength of the heat treated extruded and rolled thread and the strength of the heat treated cut thread is about equal if the chemical composition and the heat treatment are the same for both types.

Cut threads usually give the appearance of having a closer fit than is actually the case, due to small feather burrs and irregularities left by the cutting tool. The rolled thread is always smooth. Slight variations within allowable limits may be present in cut threads due to wear on chasing dies; rolled threads in any given lot are all practically alike but do not have a finished point. The finished point is necessary on cut threads to facilitate assembly operations, since the razor edge left on the crest of the last thread by the die chasers is easily damaged or burred. In the rolled thread, the rolling operation leaves the crest of the last thread in a rounded shape which is not easily damaged. As a final comparison, cut threads usually cost more than the rolled or extruded and rolled types.

Irrespective of the forming technique, threads for most common bolts and screws are designated as American Standard (National) and are available in both a coarse thread and fine thread series. The coarse series is recommended for general use in engineering work and machine construction where quick, easy assembly is desired; the fine thread series is recommended for general use in automotive, aeronautical, and similar work where conditions require a fine thread and minimum weight.

Both Coarse- and Fine-Thread Series can be obtained. The classes of thread tolerance generally used in the past were referred to as Class 2 and Class 3. Recently a new American Standard system of screw threads has been adopted, and under this new system fasteners generally will be produced to Class 2A for the bolt or screw and Class 2B for the nut. Similarly, there is Class 3A and 3B for certain special parts, and there may be some use of the old Classes 2 and 3. A feature of the Class 2A bolt or screw is that it has a positive allowance. In other words, the maximum thread pitch diameter is less than basic by a small amount. This allowance is useful in preventing seizure in high cycle wrenching or at high temperatures, and also provides a space for electroplating. In addition there are so-called Class 5 fits which are wrench-tight, but these are not well standardized and are presently under development. This class is commonly used for studs or screws and their mating tapped holes where considerable force is required for assembly.

Bolts and screws can be obtained with many different types of heads. These range through the more or less common varieties to the specially-designed, odd-shaped types used for special applications. The use of lesser-known types, however, often results in a sacrifice of some needed quality that is usually found in the normal-type head and greatly increases the unit cost because of the special fabrication their design entails. For this reason, every effort should be made to minimize the use of specially-designed bolts and screws.

Several types of screws and bolts are listed in Table I and Table II, respectively.

Nuts

Nuts are currently produced in such a wide variety of types and styles and from such varied materials that the selection of the best possible combination of strength, accuracy, value and reliability for a given application presents a complex problem to the engineer. For most applications, there is little need for specifying special types, since there is usually some standard nut commercially available that will not only serve the purpose but result in considerable savings over special fabrications.

As in the case of bolts and screws, the threads comprise the most important element of a nut. The threads for most common nuts are designated as American Standard (National), and are available in both a coarse and fine series; each, in turn, obtainable in the classes of fits discusseed for bolts and screws.

Nuts are commonly supplied in three degrees of finish. Unfinished nuts are left in the rough state. They are hot forged, or hot or cold punched and are not machined on any surface except for the threading operations. Semi-finished nuts are machined on the bearing surface only to provide a washer face. The tolerances across the flats and the thickness are closer than for unfinished nuts. Finished nuts are machined on all surfaces, and the tolerances are the same as for semi-finished nuts. The bearing surface is washer-faced. Semi-finished nuts that are blanked from cold-drawn hexagonal or square rods are considered to fall within the finished-nut category.

In addition to the common square and hexagonal types of nuts, several other styles are readily available to meet the particular requirements imposed by certain applications. These styles include the cap, wing, knurled, slotted and castellated types. In this connection, it should be noted that, although the slotted and castellated nuts appear to be similar in both design and function, there are certain distinct differences between the two. Slotted nuts are full nuts of either American Standard Heavy, Regular, or Light pattern, with three slots milled through the flats of the hexagon. Castellated nuts have a cylindrical top through which the three slots are milled, leaving the hexagon surfaces in the base solid. In both types, cotter pins or wire are passed through the slots and through drilled holes in the bolt to effectively prevent the nut from turning.

There is a wide variety of lock nuts on the market today. Virtually all of these are designed to function on the same general principle: providing a gripping action on the bolt threads to prevent back-off and subsequent loosening. Some of the types available accomplish this by distortion of the entire nut during manufacture; some by distortion of the nut in application through pressure against the work. Some hold the bolt by less than one full thread; others utilize nonmetallic inserts which the bolt must tap as it enters. Most are of one-piece construction or consist of unit assemblies, while some are of the two-piece type. A few, in addition to preventing the nut from turning, provide increased thread pressure in a longitudinal axis to compensate for bolt stretch, or wear of bolted components, thus assuring a tight fastening even under the most adverse service conditions.

Several types of nuts are listed in Table III.

Washers

Washers are extremely useful accessories in modern fastening methods. The many

Table I—Types of Screws

Type of Screw	Materials from which usually made	Advantages	Limitations	Applications
Cap Screws	Low carbon steel (approx. 0.20% C), medium carbon steel (approx. 0.35 to 0.42% C), high carbon steel, bronze, brass, stainless steel, Monel, Everdur, aluminum	Available in a variety of heads: fillister, flat, hex, socket, etc.; can be finished in many ways: mirror finish, heat treated black satin finish; plated, etc.; oxidized. In some applications, socket head cap screws are more advantageous than hexagon or flat head types because their design calls for key wrench application which in certain cases offers added hand leverage and cuts assembly time.	For socket-headed screws, proper wrench must always be available for any retightening that becomes necessary. No threaded pressure obtained unless supplied through supplementary source such as lockwashers, etc.	For general fastening in either tapped holes or with nuts. Used extensively in production items such as machine tools, automotive equipment, farm machinery, aeronautical equipment, etc.
Self Tapping Screws	Case-hardened steel, stainless steel, aluminum	Simplify assembly work; save operations, eliminate production bottlenecks; tapping of holes eliminated; no tapping plates, lock washers or inserts required. Eliminates riveting in tight spaces. Available in a variety of heads: round slotted, Phillips recessed, hex, clutch, pan, oval, etc.; available in variety of finishes: plain steel, nickel plated, brass plated, cadmium plated, bronze plated, copper plated, blue oxidized, etc.	Not completely adaptable for light gage parts requiring continued assembly and disassembly. Stainless steel screws cannot be brought up to very high degree of hardness, hence can only be applied successfully to relatively soft materials such as light gages of mild sheet steel, aluminum, brass, copper, etc.; and in aluminum and die castings, plastics, etc. For most sheet assemblies, coarse-pitch thread self-tapping screws are satisfactory, but in materials of a crumbling or granular nature, such as gray and malleable iron castings, a screw having tap characteristics is better. No thread pressure obtained unless supplied through supplementary source.	For making fastenings to sheet metal from 28 gage (0.015 in.) to 6 gage (0.203 in.). Useful for aluminum, die castings, plastics, fiber, hard rubber, etc. Hex-headed, heavier-thread types used for making fastenings to sheet metal up to 6 gage (0.203 in.); to steel plate and structural shapes up to ½ in. thick; useful for brass, die castings, etc. 
				For joining light sheet metal and fastening to sheet metal up to 18 gage (0.050 in.). 
				For making fastenings to malleable and gray iron castings, aluminum and zinc castings, heavy gage sheet metal and plastics. Screw actually cuts thread in material; useful when assembling products which must be serviced in the field. 
				For making permanent fastenings to iron, brass, and aluminum castings, steel, plastics, etc. Screws form own thread in material as they are hammered in or otherwise forced into a hole of suitable size. Can be applied with hopper-fed machines. Pointed types used for fastening fabric, fiber, leather, cardboard, etc., to sheet metal. Screw is hammered into a drilled, punched, or pierced hole. 
Set Screws	Brass, bronze, stainless steel, Monel, Everdur, aluminum, low carbon steel, medium carbon steel, high carbon steel	Available in wide variety of heads: recessed socket, headless slotted, recessed clutch, Phillips recessed multiple spline, square, etc. Can be finished many ways: plated, black satin, recessed head set screws, permit smooth flush surface by eliminating protruding heads; improves product appearance; safer, particularly on moving parts. Available in wide variety of points: cone, flat, oval, half-dog, full-dog, cup, etc.	For socket head screws, proper wrench must always be available for any retightening that becomes necessary. Excessive torque applied to low strength, square head types will cause twisting off in tapped holes. No thread pressure obtained unless supplied through supplementary source.	Widespread use on production line items such as office machinery, machine tools, household equipment, automotive and aeronautical equipment, etc.
Machine Screws	Carbon steel, brass, silicon bronze, Monel, stainless steel, Everdur, aluminum	Available in wide variety of heads: flat, round, oval, fillister, truss, binding, Phillips, clutch, pan, hex, square, upset hex, one-way slot, notched, cock, lentil, jackson, undercut, etc.	Generally, machine screws under 2 in. in length are threaded to the head, but those over 2 in. long are only threaded 2 in. up the shank. No thread pressure obtained unless supplied through supplementary source.	For general fastening in either tapped holes or with nuts. Used extensively in production items such as electrical equipment, automotive equipment, etc.
Lock Screws	Brass, bronze, K-Monel, stainless steel, phosphor bronze, carbon steel	Adaptable to applications where vibration or corrosion are encountered; designs prevent any backward movement of screw. Also available in locking set screw form.	Repeated usage may result in weakened torque and holding power.	Particularly applicable to water faucets and plumbing fixtures where a corrosion resistance and constant tightness is required. A proprietary fastening manufactured by Shakeproof, Inc. 

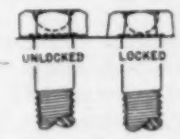
(Continued on next page)

styles or types available are used to fulfill many needs arising from the application of threaded fastening devices. Basically, washers comprise three distinct classifications: plain, anti-turn, and spring.

The plain washers are used solely for decorative or bearing-surface applications. In these, they provide for a distribution of the loading over a wider area of the work surface than that encompassed by the bolt head or nut alone. In addition, they prevent damage to the work surface when the nut is tightened down or if the bolt head happens to turn during assembly. Plain washers are available in many patterned, countersunk, ridged and formed varieties, but none of them provide any extra pressure on bolt or nut threads and none prevent the nuts from loosening.

The anti-turn, or tooth-type, lock washer is used primarily to prevent a nut from backing-off under severe vibration. The individual, hardened teeth are designed to bite into both the work surface and the bolt head or nut and thus prevent turning and subsequent loosening. The tooth-type washer, however, does not provide any appreciably

Table I—Types of Screws—(Continued)

Type of Screw	Materials from which usually made	Advantages	Limitations	Applications
Lock Screws	Brass, bronze, K-Monel, stainless steel, phosphor bronze, carbon steel	Built-in locking feature consisting of nylon insert set into one side of thread segment. In operation, plug exerts lateral thrust causing tight mating of threads on opposite side of screw. Withstands operating temperatures above 250 F. No distortion of threads.	Repeated usage of screw results in slight loss of torque and holding power.	Applicable for use where high temperatures or rough vibration is encountered or where good appearance is mandatory, since no washer locking devices are used. A proprietary fastening manufactured by Diamond Head Screw Corp. 
		Concave head and counterbored bearing surface results in spring action when bolt is set up tight. Locking action resists fatigue failure and loosening.	Repeated usage may result in weakened spring action and consequent loss of thread pressure.	Applicable for conditions of severe vibration such as cylinder heads, flywheel housings, bearing caps, etc. A proprietary fastening manufactured by Lamson & Sessions Co. 

increased thread pressure to compensate for bolt stretch, wear, etc.

The underlying principle of the spring-type lock washer is to compensate for any loosening that might occur between the component parts of bolted assemblies. Loosening can be the result of improper tightening during initial installation, the result of excessive vibration, or caused by any expansion, contraction, stresses, or wear of the components that occurs after final assembly has been made. Nonfatiguing properties and automatic reactive pressure are essential in spring-type washers, since it is the spring action that justifies their use.

Combination spring and tooth-type lock washers combine the advantages of both types in that continued pressure is exerted on the threads and the sharp tangs or teeth impinge on the work surface and/or nut to prevent turning under extreme service conditions.

All three basic types of washers are available with screws as permanently assembled units. In these, the washer is slipped onto the screw blank before the threads are rolled. The threads hold the washer on the screw but allow it to rotate and properly seat itself when the screw is tightened down. The advantage such assemblies present are readily discernable in that they reduce assembly costs and time, eliminate awkward assembly problems, save screws and washers wasted in assembly, insure use of correct washer, and insure that all screws have washers where specified.

Several types of washers are listed in Table IV.

Studs

Studs are commonly used in place of bolts or cap screws on a great variety of manufactured products. They are usually mounted in a tapped hole and have a nut threaded on the upper, or exposed, end.

Generally speaking, threaded studs are divided into three basic categories, or types: (1) tap-end studs, (2) double-ended studs, and (3) continuous-thread studs. All three types are usually supplied with both ends flat and chamfered 35 to 40 deg. with the end of the stud. The length is measured from one extreme end to the other end, and the thread length is usually taken from the extreme end of the stud to the last perfect thread. The maximum amount of imperfect thread commonly permitted beyond the last perfect thread is 2½ threads.

Tap-end studs are used where one end of the stud is to be driven either manually or by power into a tapped hole. Such studs, when properly installed, can only be removed by force since the end in the hole is usually threaded with a Class 5 fit. Studs of this type can also be obtained with a variation of the Dardelet locking thread on the tap end. Such threads effectively reduce the danger of loosening due to vibration by producing the equivalent to a perfect selective fit and placing the female threads under high compressive pre-stress. The exposed end of the stud is threaded with either a Class 2 or a Class 3 fit for the nut.

Double-ended studs are used in place of a bolt (or as a tie rod) with a nut on each end. Both ends are threaded alike, usually with a Class 2 or Class 3 fit as desired.

Continuous-thread studs are threaded with one continuous thread for their entire length, the fit being either Class 2 or Class 3 so as to take a nut along from one end to the other. Studs of this type are commonly used in applications identical to those of the double-ended type, but where a shorter stud-length is required.

Studs can also be effectively mounted for use in other ways without the necessity of drilling, tapping and tightening operations. Outstanding among these alternative mounting methods are those in which the stud is either electrically welded to a metal surface, or pushed into the surface by means of a powerful, powder charge.

The first of these methods makes use of a flux-filled stud, threaded on one end only. The butt end of the stud is surrounded with a porcelain ferrule (later removed) which shields the arc, restricts impurities, and confines the molten metal during the welding operation. Welding is accomplished with specially-designed manual or automatic guns, and extremely rapid installations can be achieved.

The other alternative method of stud installation makes use of a special gun and a powder charge. In this method, the stud that is used is threaded on one end only, the other end being sharply pointed so as to facilitate entering when driven into the mounting surface by the exploding charge. Rapid installation is likewise assured with this technique.

Several types of studs are listed in Table V.

Rivets

Rivets have long been considered one of the simplest fastening devices used in engineering. When properly installed, they provide a strong and positive bond between two or more assembled parts and often result in production economies unattainable with other fastening methods.

Rivets are commonly considered to comprise four separate types: solid, split, tubular, and blind. All but the latter of these require access to both sides for installation, since heading and bucking operations must be performed. Where it is difficult or impossible to reach both sides of the work, blind rivets are used. These are produced in a variety of types, styles and sizes, but in fundamental principles, their action is the same: The rivets are inserted and set from one side only. The setting operation can be performed by the mandrel-like action of a plug pulled entirely through the rivet-body; by a plug pulled partially through and then severed; by a squeezing action that results from an internally-threaded portion of the rivet-body being drawn up behind the joined sheets; or by a flaring action that results from detonation of an explosive charge in the shank of the rivet proper.

The solid, split, and tubular rivets are all headed in basically the same manner, *i.e.* either rolled, spun, spread or flared, depending on the type. These heading operations require not only access to both sides of the joint, but sufficient room to maneuver the necessary guns, hammers, dollies, etc. that may be required.

Several types of rivets are listed in Table VI.

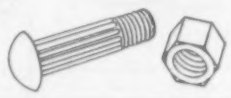
Staples

Stapling and stitching various metallic and nonmetallic materials constitutes one of the most rapid and versatile fastening techniques in industrial use today. Since this method of fabrication requires no punching or drilling of holes, no pre-cleaning operations, no heating or cooling time, no assembling or tightening operations, and no post-fastening care, it results in considerable savings of time and money.

Basically, stitching is the term used to denote the fastening operation wherein a length of wire is cut from a coil and formed into the fastener as each stitch is made, whereas stapling employs pre-formed fasteners. However, the finished fastening appears the same in both cases.

The stitching, or stapling, capacity of steel and other metals varies considerably with the type and hardness of the material. In mild steels, such as soft-rolled sheets (SAE 1010 to 1020), the maximum total thickness that can be stitched is approximately

Table II—Types of Bolts

Type of Bolt	Materials from which usually made	Advantages	Limitations	Applications
Stove Bolts	Carbon steel, brass, silicon bronze, Monel, stainless, aluminum	Available in variety of heads: Flat, round, truss, Phillips, etc. Usually furnished with square nuts; very similar to machine screws, except that threads are usually rolled instead of being cut.	Stove bolts up to 2 in. long are usually roll threaded to the head, but those over 2 in. long are only threaded about 2 in. No thread pressure obtained unless supplied through supplementary source.	For general fastening in either tapped holes or with nuts. Used extensively in production items such as electrical equipment, household goods, etc.
Machine Bolts	Naval bronze, silicon bronze, Monel, stainless, carbon steel, aluminum	Machine bolts make a snug, full-bodied fit into both tapped and drilled holes since short length bolts are threaded to the head and longer lengths have a full size shank equal in length to the diameter of the bolt. Usually furnished with American Standard Regular hex nuts. Available in wide variety of heads: Hex, square, eccentric, loom, button, patch, tee, flat, etc.	No thread pressure obtained unless supplied through supplementary source.	For general fastening in either tapped holes or with nuts. Silicon Bronze machine bolts used widely in outdoor electrical applications and in marine work because of resistance to "season cracking" and atmospheric corrosion. Machine bolts of other metals used extensively in such production items as automotive equipment, agricultural machinery, etc.
Carriage Bolts	Naval bronze, silicon bronze, Monel, stainless, carbon steel, aluminum	Available in either oval or square neck design. Both oval and square necks prevent bolt from turning if used in proper size hole. Furnished with or without nuts.	Although carriage bolts are threaded as close as practicable to the neck on the short bolts, the longer bolts only have a maximum of 2 in. thread. No thread pressure obtained unless supplied through supplementary source.	Oval neck bolts particularly suited to fasten castings and forgings because neck design offers greater tolerance of fit and is generally more adaptable.
Lag Bolts	Naval bronze, silicon bronze, Monel, stainless steel, carbon steel, brass, aluminum	Lag screws and lag bolts are one and the same thing, the terms being used interchangeably. Lag bolts of a given length have the same length of thread regardless of bolt diameter. Usually supplied with square heads and gimlet points.	Lag bolts can be reused, but the reuse of holes formed by the lag threads is limited because of considerable reduction in holding strength.	Used for wooden construction; mostly marine, irrigation equipment, water storage tanks, framing, trestles, vats, troughs, etc.
Hanger Bolts	Naval bronze, silicon bronze, carbon steel, aluminum	All hanger bolts of the same length have the same length of thread regardless of diameter. This applies both to the machine thread and the lag thread. Usually supplied with American Standard Regular hex nuts. Lag threads have gimlet point.	Hanger bolts can be reused, but the reuse of holes formed by the lag thread is limited because of considerable reduction in holding strength. No thread pressure obtained on machine threads unless supplied through supplementary source.	Used for suspending members for overhead construction such as ventilation ducts, piping, conduits, fixtures, etc.; or for securing pedestals and bases such as machinery, apparatus, etc., to decks, walls, ceilings, etc.
Strut Bolts	Naval bronze, silicon bronze, Monel, carbon steel, aluminum	Usually supplied in unslotted oval head form and with American Standard Regular nuts, but slotted heads are available.	No thread pressure obtained unless supplied through supplementary source.	Used extensively for strut, brace, and bracket assembly. When supplied with slotted heads, can be used effectively as oval-headed machine bolts.
Dardelet Bolts	Carbon steel	Combines advantages of both rivets and bolts. When bolt is driven into hole, axial ribs on shank are deformed and grip inner surface of hole to provide a body-bound fit. Nut locks securely when wrenched down, as unthreaded counterbored section of nut rides up on axial ribs of bolt shank. Can be reused and is not loosened by vibration or shock.	Bolt must be driven into hole to assure a tight, body-bound fit, thus limiting its application on comparatively fragile structures.	Used extensively for heavy construction purposes, machinery applications, etc., where a rigid and vibration-proof fastening is required. A proprietary thread developed by the Lock Thread Corp. 

0.085 in., no single sheet of which exceeds 0.062 in. in thickness. Although harder steels, such as hot-rolled sheets, stainless, and other alloys can be stitched, the maximum thickness is somewhat less than with the softer metals.

In aluminum, the ST grades can be satisfactorily stitched up to a maximum thickness of about 0.085 in., providing the thickness of no single sheet exceeds 0.051 in. In the softer grades, maximum stitching thickness is approximately 0.110 in., with no single sheet exceeding 0.065 in.

Copper sheets can be stitched up to a maximum thickness of 0.188 in. if no one sheet exceeds 0.100 in. In multiple sections, thicknesses beyond this maximum can be joined. All of these maximum stitching thicknesses are based on the use of No. 18 gage steel wire (0.0478 in. dia.) having a tensile strength of 290,000 psi. For softer or thinner materials, lower strength wire is customarily used.

Types of staples are listed in Table VIII.

How to Select a Fastener

From the foregoing, it can readily be seen that mere choice of a type or style of fastening device from the variety available is not enough for completely satisfactory results. In addition, the factors of strength, the types of materials being joined, and the service conditions to which the fastened assembly is subjected must likewise be considered. This latter group includes possibilities of anticipated exposure to corrosive atmospheres and temperature extremes; special assembly and subsequent disassembly requirements, if any; consideration of outward appearance if ultimate sales of fastened product are contingent upon this factor; relative costs of comparable fastening techniques; ease of installation, and the like. All of these conditional factors will exert varying degrees of influence, depending upon the application in question.

To satisfactorily meet these varied service conditions, fasteners, in addition to being available in many different styles or types, are fabricated from many different materials. In general, when evaluating the various materials from which fasteners are made, the physical form in which the material is to be used must always be considered. The characteristics of the materials, when used for fastenings, may vary widely from the characteristics of the same material when used for other purposes such as valves, tanks, pipe, etc. The reason for this lies in the fact that fasteners, by virtue of their definition, are usually subjected to continuous and highly stressed conditions. The ability of a fastener to function successfully under such conditions depends in a large measure on its residual cross-sectional area of sound metal. Since this cross-section is often reduced through threading, collaring, etc., or by the internal attack which accompanies the phenomenon known as "stress-corrosion," premature failure can result, even though the material itself is adequate for structures of larger size or less-stressed conditions.

In this connection, special problems involving dissimilar metals frequently arise in the selection and specification of fastening devices. To obviate the galvanic corrosion that results when metals are placed in contact with other metals of higher potentials, fasteners are quite often manufactured from the same or similar metals with which they are used. But variations to this are not infrequent in certain types of work, especially where the net effect of such corrosive action on the relatively small percentage of exposed surface is more than offset by the increased strength, better holding power, and all-around suitability of fasteners fabricated from a metal dissimilar to that being joined.

Carbon steel fastening devices comprise the great majority of headed and threaded fasteners in industrial use today. They are used primarily where comparatively low cost joining and average strength is desired. Since most fasteners should have a moderate degree of plasticity so as to achieve a gradual rather than an abrupt or sudden rupture, they are rarely made from high carbon steel. Instead, low or medium carbon compositions subsequently heat treated to produce the desired plasticity are used. Carbon steel fastenings can be produced by either cold or hot forming techniques. Cold forming is by far the most popular, particularly with the low carbon groups because of the low initial cost and the savings accruing from heading, trimming, and threading operations. However, the tensile strength of cold-formed low carbon fasteners is not as great as that

Table III—Types of Nuts

Type of Nut	Materials from which usually made	Advantages	Limitations	Applications
American Standard Heavy Nut	Carbon steel, brass, naval bronze, silicon bronze, Monel, stainless steel, aluminum	Available in Full and Jam Nut sizes. Provide greater bearing surface than can be supplied by regular or light nuts. Top surface flat and chamfered; bearing surface is washer-faced. Standard class 2 fit facilitates assembly and disassembly operations. Hex and square shapes.	No provision for excess thread pressure to prevent loosening by vibration. Sharp corners of square shapes may mar work surface.	For general stud or bolt fastening on heavy equipment such as farm machinery, automotive equipment, marine and earth-moving equipment, etc.
American Standard Regular Nuts	Carbon steel, brass, naval bronze, silicon bronze, Monel, pure nickel, stainless steel, aluminum	A general service type of nut. Top surface is flat and chamfered; bearing surface is washer-faced. Standard class 2 fit facilitates assembly and disassembly operations. Available in Full and Jam Nut sizes. Hex and square shapes.	No provision for excess thread pressure to prevent loosening by vibration. Sharp corners of square shapes likely to mar work surface.	For general stud or bolt fastening on moderately heavy equipment such as automotive, aeronautical, etc.
American Standard Light Nuts	Carbon steel, brass, silicon bronze, Monel, stainless steel, aluminum	A general service type of nut. Top surface is flat and chamfered; bearing surface is washer-faced. Standard class 2 fit facilitates assembly and disassembly operations. Available in Full and Jam Nut sizes.	No provision for excess thread pressure to prevent loosening by vibration.	For general stud or bolt fastening on light equipment such as household goods, toys, light tools, etc.
Castellated Nuts	Carbon steel, brass, Monel, stainless steel, aluminum	Milled slots in upper segment provide for wire or cotter pin. Positive locking action assured providing excessive vibration, does not break wire or cotter pin.	Bolts or studs must be drilled through at milled slot to provide for wire or cotter pin. Extra installation work and expense entailed.	Used extensively with bolts or studs in applications where a positive locking action is required such as flywheel housings, transmission cases, cylinder heads, etc.
Machine Screw Nuts	Carbon steel, brass, silicon bronze, Monel, stainless steel, aluminum	Available in both hex and square shapes. Hex shapes can be double chamfered if required.	Sharp corners of square shape likely to cause marring of work surface. No provision for excess thread pressure to prevent loosening by vibration.	For general fastening with machine screws or studs. Used extensively in production items such as electrical equipment, automotive equipment, etc.
Hexagon Cap Nuts	Carbon steel, brass, Monel, stainless steel, aluminum	Washer-faced to prevent marring work with sharp corners; have a slight counterbore to protect first thread in plating operations. Can be plated for decorative uses.	Limitation on threaded length of bolt or stud used. No provision for excess thread pressure to prevent loosening by vibration.	Used extensively for utility as well as appearance on instrument panels, etc.
Wing Nuts	Carbon steel, brass, silicon bronze, Monel, stainless steel, aluminum	Usually cold forged to present a smooth, clean finish. Especially designed for manual and rapid assembly and disassembly operations. No tools required.	Definite limitation on tightness since manually installed. No provision for excess thread pressure to prevent loosening by vibration.	Used extensively for inspection plates, covers, lids, etc., and all applications requiring manual fastening and subsequent unfastening.
Knurled Nuts	Brass, carbon steel, aluminum	Provide a rapid means for manual adjustment, assembly, and disassembly operations. No tools required.	Definite limitations on tightness since manually installed. No provision for excess thread pressure to prevent loosening by vibration.	Used extensively for instrument and electrical apparatus.
Self-Locking Nuts	Stainless steel	Spring action in crest of nut exerts continuous pressure on bolt or stud threads. Good torque retention and re-usability. Withstands high temperatures and cannot be shaken loose.	—	Used primarily for aircraft and jet, gas turbine, and reciprocating engine service; where an all-metal, shake-proof nut is required to withstand extremely high temperature. A proprietary fastening known as "Hex-Lock" and manufactured by Boots Aircraft Nut Corp. 
	No. 1020 Cold drawn steel	Three-sided crimp in crest of nut exerts continuous pressure on bolt or stud threads. Made to American Standard Light Nut Specifications. Cannot vibrate loose: locks on any portion of bolt or stud. Can be reused.	—	Widely used for applications where severe vibration occurs, such as automotive equipment, railroads, marine equipment, machinery, etc. A proprietary fastening known as "Trilock" and manufactured by Boots Aircraft Nut Corp. 
	Cadmium-plated steel; anodized aluminum alloy	One-piece all-metal construction: withstands severe vibration; top locking section has out-of-phase threads; load-carrying lower section has thread strength of standard nut of comparable size. Two sections connected by spring member which is an integral part of unit. Axial thread play is reduced. Locking force of spring member constant; nuts can be removed and reused without impairing efficiency.	—	Particularly adapted to airplane construction because of lightweight and high holding strength. Used extensively for engine cylinder heads, valve covers, housings, etc. A proprietary fastening known as "Rol-Top" and manufactured by Boots Aircraft Nut Corp. Other proprietary types, similar in function and manufactured by the same company, are available in wing and bellows styles. 
	High carbon steel	One-piece, all-metal construction; threaded portion of locking crown collar heat-treated and distorted from the round on opposite sides so as to grip bolt or stud threads when engaged. No pitch interference, since threads have same lead throughout.	Slight reduction in torque with repeated use.	Suitable for most machinery applications requiring a vibration-proof fastening and high holding strength. A proprietary fastening manufactured by Lamson & Sessions Co. 

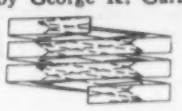
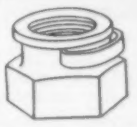
(Continued on next page)

which can be obtained from heat treated medium carbon steel.

Hot formed carbon steel fasteners can be produced readily from material receiving no further heat treatment, the most obvious way of increasing the strength being to increase the carbon content and, secondly, the manganese content of the material. However, these additions of carbon and manganese should not reach such proportions as to reduce the plasticity of the fastener to an unsafe limit. Usually the limitations are governed by the ease with which the material can be machined or threaded. Since most hot-formed fasteners are machined or cut-threaded in the cold state, sulfurized carbon steels are widely used to facilitate these operations.

Stainless steel fastenings are used where high tensile strength, corrosion resistance, and permanent finish are desired. Several types of stainless steel are available, each of which varies with its percentage of chromium, nickel, and carbon. Other ele-

Table III—Types of Nuts—(Continued)

Type of Nut	Materials from which usually made	Advantages	Limitations	Applications
Self-Locking Nuts	Carbon steel, brass, silicon bronze, aluminum	One-piece, all-metal construction; locking action obtained by elliptical spring grip in upper section of nut that results from uniform squeeze against opposite flats during manufacture. Bottom of nut remains circular; only top section is squeezed.	Slight reduction in torque with repeated use.	Suitable for most machinery applications requiring a vibration-proof fastening and high holding strength. A proprietary fastening manufactured by Stover Lock Nut & Machinery Corp. 
	Carbon steel, cadmium-plated, anodized dural, brass; brass, cadmium-plated; brass, nickel plated	Locking element is compressible, unthreaded and elastic; bolt impresses threads and compresses collar. Nut locks to bolt in any position and fully seats metal threads. Nut is removable and can be reused. Elastic collar retains grip after repeated use, and effectively seals threads against liquid seepage. Available in various forms: anchor, standard height hex, thin hex, clinch, spline, cap, wing, etc.	Definite limitation on temperatures and fluids to which nut can be exposed because of elastic collar insert.	Suitable for most machinery applications requiring a vibration-proof fastening and high holding strength. A proprietary fastening manufactured by Elastic Stop Nut Corp. of America. 
	High carbon steel, aluminum, stainless steel, bronze	A threaded helical spring coiled with a greater pitch than the thread to which applied. Gripping action is effective whether bolt is in tight or loose position. Due to diametric shape of unit, and because the outside diameter is small; it can be used effectively in applications with limited clearances. Controlled heat treating assures longer life and repeated use of nut; deformation and thread stripping reduced.	Special hand or power-driven tools required for production line installation.	Suitable for most machinery applications requiring a vibration-proof fastening and high holding strength. A proprietary fastening manufactured by George K. Garrett Co. 
	Spring steel, cadmium-plated	Single thread self-locking nut. Inner section arches upward and is spirally formed to freely engage bolt thread. After wrench tightening, spring forces are exerted downward on load, inward and upward on bolt. Available in various forms: hex, wing, washer base, cap, etc.	Can be used as a load carrying nut for light assemblies only. Limited to use as a locknut on top of regular load carrying nut on heavy assemblies.	Suitable for most applications where a vibration-proof fastening is required. A proprietary fastening manufactured by the Palnut Co. 
	Carbon steel	Locking action obtained by snap ring pivoting within nut. Can be used with or without serrated bolt. If bolt is serrated, one end of snap ring engages nearest serration on bolt thread; if plain bolt is used, ends of ring bite into thread. Snap ring does not limit travel of nut and is a permanent part of nut.	Snap ring, when locked, prevents nut from turning but does not provide increased thread pressure to compensate for bolt stretch or wear.	Suitable for most applications where a vibration-proof fastening and high holding strength is required. A proprietary fastening manufactured by Simmons Fastener Corp. 
	Carbon steel, stainless steel	All-metal locknut with locking ring permanently inserted and forming an integral part of nut. When nut is tightened, pressure forced locking ring to flow inward around bolt threads, thus removing all axial play from assembly. Locking ring stays deformed after use and nut can be reused. Not affected by high temperatures. Available in variety of forms: double chamfer hex, single chamfer hex, thin, cap, etc.	—	Suitable for most applications requiring a vibration-proof fastening and high holding strength. A proprietary fastening manufactured by the An-Cor-Lox Div., Laminated Shim Co., Inc. 
	Spring steel	Self-locking nut of one-piece construction. As nut is tightened, two prongs are forced against root of bolt thread, and arch in prongs and base is flattened thus producing an upward and inward thrust against screw threads and a spring lock for resistance to vibration loosening. Nuts can be tightened in limited space. Free-acting prongs can compensate for variations in thread tolerance. Available in many possible variations of basic design such as "U" type, flat latch type, push-on type, etc.	—	Suitable for most applications requiring a vibration-proof fastening, high holding strength and rapid assembly. A proprietary fastening known as "Speed-Nut" and manufactured by Tinnerman Products, Inc. 
	Low carbon steel	Essentially a threaded bushing with a substantial base combining functions of a nonturning nut and a washer. Projections on base prevent nut from turning during assembly or subsequent operations. Available in wide variety of sizes and flange designs. Pronged-flange type used for fastening in plywood, wood, and metal assemblies; bossed-flange type for projection welding to metal assembly components; and plain-flange type for spot-welding installation. Reduces tapping operations in metal assemblies and provides a steel thread for increased holding power and strength in non-metallic materials. Some styles are available with bumped barrel to put friction on screw threads and some styles have fingers or lugs extending over top of barrel to grip screw threads and thus achieve a self-locking feature.	Prongs on base prevent turning only. No excess thread pressure on type shown to compensate for bolt stretch or wear and no provisions made to keep screw from loosening due to vibration.	Suitable for most applications requiring a nonturning nut and high holding strength. Particularly well-suited for fastening non-metallic materials. A proprietary fastening known as "Teenut" manufactured by United Carr Fastener Corp. 

ments are sometimes added in minute quantities to change the general properties of the basic type. The principal types of stainless steels used for fastenings are as follows: Type 302 is a general purpose 18:8 chromium nickel composition that has excellent cold-forming and fair machining properties. It can be hardened only by cold-working, and retains an untarnished surface under most atmospheric conditions. It offers high strength at reasonably elevated temperatures.

Type 303 possesses exceptional non-galling and non-seizing properties and can be hardened only by cold-working. It is a free machining grade of the standard 18:8 type and is highly satisfactory for fasteners subjected to friction and wear.

Type 304 is an 18:8 grade generally used for cold-headed fastenings such as rivets, machine screws, bolts and capscrews. It is superior to Type 302 in corrosion resistance and can be hardened only by cold-working.

Type 310 is a chromium nickel stainless steel with a ratio of 24 to 26 chromium and 19 to 22% nickel. It offers the highest heat-resisting qualities of any of the chromium

Table IV—Types of Washers

Type of Washer	Materials from which usually made	Advantages	Limitations	Applications
Plain Washers	Copper; brass; brass, nickel plated; silicon bronze; Monel; stainless steel; pure nickel; carbon steel; aluminum	Provide bearing surface for bolt heads or nuts and thus distribute loading over wider area. Prevent marring of work surface when nut is tightened down or if bolt head happens to turn. Provide better product appearance.	Do not provide increased thread pressure to prevent loosening due to vibration, and do not prevent bolt or nut from turning.	Used extensively for most nut and bolt or stud applications.
Countersunk Finishing Washers	Brass; brass, nickel plated; steel, chromium plated; stainless steel; carbon steel; Monel; aluminum	Supplied in both flush and hollow types. Provide good bearing surface on flat work for countersunk flat or oval head machine screws. Hollow-type eliminates necessity of countersinking work surface to accommodate countersunk screw heads. Increases product appearance. Particularly useful on soft materials, plastics, etc.	Do not prevent screw from turning and do not provide increased thread pressure to prevent loosening due to vibration. Sharp downturned edges cut into work surface when screw is drawn down snug.	Used extensively on automotive equipment, household items, laboratory apparatus, etc.
Split Type Lock Washers	Silicon bronze, Monel, carbon steel, stainless steel, aluminum	Spring action in washer helix provides increased pressure on bolt and nut threads to prevent loosening by vibration. Washers can be reused with little reduction in spring action.	Washers tend to mar work surface where tang of helix impinges on work. High temperature applications can draw temper of washer.	Used extensively for most plain threaded fastenings.
Tooth Lock Washers	High carbon steel, stainless steel, beryllium copper, K-Monel, phosphor bronze	Tapered and twisted teeth bite into both work surface and bolt head or nut. Can be reused with little, if any, loss in holding power. Does not loosen under vibration. Also available as Sems units (preassembled with screws of various sizes and heads).	Washers mar work surface where teeth impinge, and do not provide any increase in thread pressure against bolt ductility, expansion, contraction, or wear. 	Recommended for use under U. S. Standard hex nuts, square nuts, hex washer-head screws; binding or pan head screws and truss or oven head screws where maximum locking efficiency is desired. A proprietary fastening manufactured by Shakeproof, Inc. Internal-tooth lock washers are recommended for use under S.A.E. hex nuts, round head screws, fillister head screws, hex head screws. Can be used under U. S. Standard nuts, binding, truss, and washer-head screws where neat appearance is desired. Countersunk tooth lock washer shown is recommended for use under flat head and oval head machine screws with 80-82 deg. countersink angles. External-internal tooth lock washers are recommended for use where a large bearing surface is necessary such as over elongated holes, oversize clearance holes, over metals with weak understructure, and over relatively soft surfaces, etc.
Dome Lock Washers	High carbon steel, stainless steel, beryllium copper, K-Monel	Available with either plain or toothed periphery. Plain units give a stiff but resilient spring action in addition to locking action of internal teeth. Dome construction absorbs shocks of sudden overloads. Eliminates tendency toward cupping or dishing when washer spans oversized holes. Toothed periphery types have all advantages of plain types plus added locking feature supplied by external locking teeth. Prevent sliding of clamped member when spaning oversized holes. Also available as Sems units (preassembled with screws of various sizes and shapes).	External locking teeth on toothed periphery type tend to mar work surface where teeth impinge. Plain units susceptible to sliding when spanning oversized or elongated holes,	Plain units used widely on hardened surfaces which resist biting action of toothed lock washers. Useful for spanning oversized or elongated holes. Toothed periphery type recommended for use on semi-rough or relatively soft surfaces. A proprietary fastening manufactured by Shakeproof, Inc. 
Spring Washers	Carbon steel	A proprietary variation of standard split type lock washer. Non-entangling feature saves assembly time and lowers costs. Can be reused. Also available as Springtite units (preassembled with screws of various sizes and shapes).	Washers tend to mar work surface where tang of helix impinges on work.	Suitable for general use and application on all types of automotive, farm implement, electrical, stove, or industrial equipment. A proprietary fastening known as "Knolink" and manufactured by Reliance Div., Eaton Mfg. Co.
	Carbon steel	Another variation of standard split type lock washer. Angle cut tends to embed helix ends more deeply in the nut, screw or bolt face and bolted surface. Non-entangling feature retained. Can be reused.	Washers tend to mar work surface where tang of helix impinges on work.	Suitable for all general applications such as those listed for the "Knolink" type. A proprietary fastening known as "Kantlink" and manufactured by Reliance Div., Eaton Mfg. Co.
	Carbon steel	A definite locking device for use with nut, screw, or bolt on soft surface material. Made in wide thin surface sections. The anchor end embeds in the surface and the turned up end engages the nut, screw, or bolt face. Can be reused.	Marring of work surface is necessary to proper operation of washer.	Suitable for use on all relatively soft surface materials such as wood, plastics, rubber, fiber compositions or soft thin sheet metal. A proprietary fastening known as "Wood Spring" and manufactured by Reliance Div., Eaton Mfg. Co. 
	Carbon steel	Non-entangling positive type spring lock washer combining features of both "Kantlink" and standard split types. Bent ends of helix assure more positive grip on nut, bolt, or screw face and on work surface to resist turning. Has much stronger tension than other types. Can be reused if tangs are undamaged.	Marring of work surface is necessary to proper operation of washer.	Suitable for general use and application on all types of equipment where extra holding power is required. A proprietary fastening known as "Nonlink" and manufactured by Reliance Div., Eaton Mfg. Co.
	Carbon steel	Double coil design provides necessary reactive pressure and reactive resilience to prevent frozen bolted assembly conditions. Washers can not mar surface of work. Can be reused without appreciable loss of spring action.	Will not prevent bolt or nut from turning, as turned-in ends of coil do not embed in either bolt head, nut, or work surface.	Suitable for all general applications such as automotive, farm implement, electrical and industrial equipment. A proprietary fastening known as "Double Coil" and manufactured by Reliance Div., Eaton Mfg. Co. 

(Continued on next page)

nickel grades, and although difficult to machine, can be readily used for cold-headed fastenings.

Type 316 is the most corrosion-resistant of the commonly used grades of stainless steel. It differs from the above grades mainly by its molybdenum content, which definitely increases its resistance to non-oxidizing acids, sea water, etc. It is also a superior composition for high temperature applications.

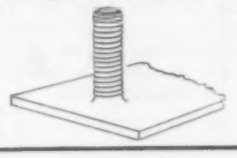
Type 317 can be hardened only by cold working and is similar to Type 316 except for a higher molybdenum content and wider application in corrosive atmospheres.

Type 321 is very similar to both the 302 and 304 group except that titanium is added to help resist intergranular corrosion when subject to operating or fabricating tempera-

Table IV—Types of Washers—(Continued)

Type of Washer	Materials from which usually made	Advantages	Limitations	Applications
Spring Washers	Carbon steel	Design permits use of thinner and more resilient steel sections. Provides greater reactive tension than that available from identical size steel sections in the helical spring washer design. Does not dig in or serrate bolted surface. Can be reused. Also available as Springtite units (preassembled with screws of various sizes and shapes).	Will not prevent bolt or nut from turning, as butted ends of washer do not embed in either bolt head, nut, or work surface.	Particularly suitable for use in quantity on aeronautical applications. A proprietary fastening known as "Springlox" and manufactured by Reliance Div., Eaton Mfg. Co.
	Carbon steel	Rib on the inner periphery wedges itself into the bolt thread and nut chamfer when under compression. Wedging action introduces reactive pressure and tension in assembly. Can be reused if rib section is undamaged.	Washers tend to mar work surface where tang of helix impinges on work.	Suitable for all general applications such as automotive, farm implement, electrical and industrial equipment. A proprietary fastening known as "Ribbed" and manufactured by Reliance Div., Eaton Mfg. Co.
	Specially processed alloy spring steel	Radiused edges avoid possibility of heat cracks. Washer can be supplied either with or without ground end deflection. Can be reused.	Washers tend to mar work surface where tang of helix impinges on work.	Particularly suitable for all applications requiring premium quality, heavy duty, or high temperature service. A proprietary fastening known as "Hy-Service" and manufactured by Reliance Div., Eaton Mfg. Co.

Table V—Types of Studs

Type of Stud	Materials from which usually made	Advantages	Limitations	Applications
Tap End Studs	Brass, naval bronze, silicon bronze, Monel, stainless steel, carbon steel, aluminum	Stud can only be removed from tapped hole by force because of Class 5 (wrench fit) threads. Other end threaded with a Class 2 or Class 3 fit for nut. Stud cannot vibrate loose in tapped hole; no thread-staking required to assure tightness. Both ends flat and chamfered 35 to 40 degrees with end of stud.	No provision for excess thread pressure on nut end to prevent nut from loosening due to vibration.	Used extensively in place of bolts or cap screws in general applications such as cylinder heads, brackets, fixtures, fittings, etc.
Double Ended Studs	Brass, naval bronze, silicon bronze, Monel, stainless steel, carbon steel, aluminum	Used in place of a bolt (or as a tie rod) with a nut on each end. Each end threaded with a Class 2 or Class 3 fit. Both ends of stud are flat and chamfered 35 to 40 degrees with end of stud.	No provision for excess thread pressure to prevent loosening due to vibration.	Used generally in such applications as automotive, farm implement, and industrial equipment, etc.
Continuous Thread Studs	Brass, naval bronze, silicon bronze, Monel, stainless steel, carbon steel, aluminum	Threaded one continuous thread for entire length. Thread is either a Class 2 or Class 3 fit to take nut along entire length. Both ends of stud are flat and chamfered 35 to 40 degrees with end of stud.	No provision for excess thread pressure to prevent loosening due to vibration.	Primarily used as a double ended stud for applications where a shorter length is required than the minimum usually furnished in the double end type.
Locking Studs	Carbon steel	An improved form of the Dardelet thread on a stud for mounting in a standard threaded hole. No selective thread fits are required. Normal working load is carried on the 6 degree angle at root of thread under high compressive prestress. Stronger in tension and torsion than ordinary American National Threads. Threads seal positively and eliminate added bosses or blind tapping. Studs are reusable; on reapplication, about ½ additional turn brings torque back to original installation value. Standard threads usually used on nut end of stud.	Studs work better in the lighter metals than in the heavier types.	Used extensively for such applications as cylinder hold-down studs, manifold studs, cylinder head studs, air brake cylinder studs, etc. A proprietary fastening manufactured by the Lock Thread Corp.
Drive Studs	Alloy steel	Eliminates drilling and tapping operations. Studs are fired into surface by means of powder charge from special gun tool. Extremely rapid installation of studs assured. Both externally and internally threaded studs available.	Definite limit on tension and torque of driven stud because of smooth stud surface.	Used mostly for applications such as oil burner casings, air conditioning ducts, sprinkler systems, etc. A proprietary fastening manufactured by Stemco Corp. 
Welded Studs	Carbon steel	Eliminates drilling and tapping operations. Flux-filled studs are end-welded with special welding gun. Extremely rapid installation of studs assured.	Materials in which studs are to be mounted must be readily weldable.	Used for covers, plates, boilers, tanks, etc. A proprietary fastening manufactured by Nelson Stud Welding Div., Morton-Gregory Corp. 

tures in the range of 800 to 1650 F.

Type 410 is a straight chromium alloy containing no nickel. It is hardenable by heat treatment up to 401 Brinell, and is considered to be a general-purpose corrosion and heat-resisting steel. It can be easily headed and has fair machining properties.

Type 416 is primarily characterized by outstanding free-machining and non-galling properties and is similar to Type 410 except that more chromium is present. Its corrosion resistance is excellent, it can be hardened up to 388 Brinell, and is suitable for fabricating studs, nuts and bolts.

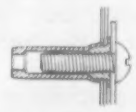
Type 430 is also similar to Type 410 but contains additional chromium and is not hardenable. The corrosion and heat resistance qualities are excellent and it offers good cold-forming and machining properties.

Type 446 is another of the straight chromium types but is non-hardenable by heat treatment. It is primarily a heat-resisting metal intended for fastenings subjected to stress and oxidation at high temperatures.

One of the most desirable properties of stainless steel fastenings is its permanent brightness and luster. Because subsequent plating is not required to enhance appearance or prevent rusting, deterioration is eliminated, and only minimum care is required to preserve the original finish of this metal. Since the threads and heads, etc., are hardened by cold working, stainless steel fastenings are particularly strong and installation difficulties and breakage are materially decreased.

Aluminum is continually broadening its scope of applications, and its use in fastenings is no exception to this. Its features of lightness, corrosion resistance to ordinary atmospheric conditions, easy cold flowing qualities, ready alloyability, and low cost are all contributing to its rapid rise. Heat treated aluminum provides ample strength for most fastening applications, and the variety of finishes it can be given permits additional sales-appeal. Aluminum fasteners permit wide use of aluminum structural members, frames, or sheets without the danger of galvanic corrosion that can occur when such structures are fastened with a dissimilar metal. Aluminum fasteners are also particularly advantageous in joining nonmetallic assemblies such as products of wood, plastic, composition, etc., since no red rust stains or streaks can mar the appearance of adjacent surfaces if the assemblies are exposed to

Table VI—Types of Rivets

Type of Rivet	Materials from which usually made	Advantages	Limitations	Applications
Blind Rivets	A17 ST Aluminum alloy for rivet, 17 ST for stem, 24ST aluminum alloy for nut, 17ST for stem, carbon steel, Monel, brass	Available in self-plugging and pull-through types with round and countersunk heads. Stem of self-plugging type is notched at predetermined point. Lower portion of stem has plug or expanded section with cylindrical upsetting head at base. With rivet installed, stem is pulled into hollow member. Plug section of stem expands rivet shank into material being fastened. As upsetting head at base of stem is pulled against shank end of hollow member, shank end expands to form a tulip head. Pull continues until stem fractures at notch. Rivet combines advantages of shank expansion, generous hole size tolerances, and generous material thickness tolerances.	Special tools required for installation. Tensile loads limited; slight reduction in holding strength when used to fasten thin sections. Cannot be reused.	Widely used for a variety of blind fastening applications in the construction, ship-building, aeronautical, automotive, sheet metal, and transportation industries for assembling tanks, structures, ducts, bodies, etc. A proprietary fastening manufactured by the Cherry Rivet Co. 
		Pull-through type designed for installations requiring a hollow fastener with positive shank expansion and high clinching action. Stem has conical upsetting head at base. Gun pulls conical head into rivet shank and forms tulip head. Head continues on through rivet expanding rivet shank as it goes. Stem is ejected on gunside of work. No stem-sections fall on blind side. Umbrella plugs available to fill holes in rivets.	Umbrella plugs required to form a water-tight riveted joint. Special tools required for rivet installation; slight reduction in holding strength when used to fasten thin sections. Cannot be reused.	Applications same as above. A proprietary fastening manufactured by the Cherry Rivet Co. 
	Low carbon steel (head and shank) spring steel (wire)	A reusable-type blind fastener consisting of a slotted-head stud and U-shaped wire spring. Unit applies in an outer sheet through a punched hole carrying notches to admit spring legs. A quarter-turn in clockwise direction puts an initial twist in the spring, draws the legs through notches so fastener will turn freely in outer sheet. Further insertion through matching perforations in one or more inner sheets, followed by another quarter-turn draws sheets together and locks. Vibration-proof and self-adjusting for varying sheet thicknesses.	Considerable time and work involved in punching, drilling, or filing necessary holes or perforations for fasteners.	Widely used for fastening moderately light gage metal assemblies such as refrigeration, air conditioning, communication equipment, etc. A proprietary fastening manufactured by the Simmons Fastener Corp. 
	Carbon steel	A thread-type blind rivet installed with a power screwdriver and special adapter to prevent rivet head from turning during installation. Rotating bit within adapter turns steel machine screw inside rivet body. Screw draws steel collar into rivet. Rivet expands as collar enters shank. Formation of blind head draws sheets tightly together. Tool can be adjusted to tighten rivet to a preset torque.	Special tools required for installation. Possibility of loosening due to vibration. Cannot be reused. Possibility of stripping threads.	Extensively used in fastening heavy gage sheet metal in such applications as tanks, truck bodies, structures, etc. A proprietary fastening manufactured by the Cherry Rivet Co. 
	17 ST Aluminum, nickel, Monel, steel, brass, copper	Explosive rivets with a deep cavity in the shank containing a small charge of heat-sensitive powder. Non-precision drilled or punched holes used. Rivet inserted in hole and head touched with electrically-heated riveting iron. Heat detonates explosive charge in rivet shank, causing shank to expand and form a barrel-shaped head or blind end of rivet. Shank expands throughout entire length thus completely filling oversize holes and assuring an all-over, metal-to-metal tight joint. Good adaptability to closely confined work areas. Rapid installation.	Special tools required for installation. Cannot be reused. Possibility of occasional duds.	Widely used for many blind fastening applications particularly in the automotive and aeronautical industries such as wing sections, fuselage sections, paneling, etc. A proprietary fastening manufactured by E. I. du Pont de Nemours & Co. 
	Aluminum, steel, brass	One-piece, internally threaded blind rivets which also serve as blind nut plates after installation. Available in flat and countersunk head styles with either open or closed ends. Also available with keys in heads to prevent turning when used as nut plates. To install, unit is threaded on pull-up stud of special heading tool and then inserted in hole. If key is used, it must be positioned to enter the keyway previously cut in edge of hole. Pull-up stud of heading tool is retracted, drawing blind side of fastener up into a tight-gripping bulge. Pull-up stud is then disengaged. Threads are left intact to receive screw when unit is used as a nut plate. Fasteners can be supplied with splines on shank for use in wood, plastics, hard rubber, etc.	Special tools required for installation. Cannot be reused. When used as nut plates, no excess thread pressure is obtained to prevent screw from loosening due to vibration. Possibility of stripping threads if excessive tool pressure is applied.	Used extensively in virtually every manufacturing field including automobiles, refrigerators, electrical equipment, household appliances, aeronautical, etc. A proprietary fastening known as "Rivnut" and manufactured by the B. F. Goodrich Co. 
	Steel, aluminum, bronze	Internally threaded blind rivets which also serve as blind nut plates after installation. Available with flat, countersunk, flush, hex, and spacer heads. Also available without tapping for nut plate. For installation, blade of special heading tool is inserted in rivet so that blade extends through barrel end slot and driver is held in head slot. Rivet is inserted in hole and barrel rotated until sleeve is pulled up against sheet on blind side. Pull-up tool is then disengaged. Rivet threads are left intact to receive screw when rivet is used as a nut plate.	Special tool required for installation. Cannot be reused. When used as nut plates, no excess thread pressure is obtained to prevent screw from loosening due to vibration. Possibility of stripping threads.	Used extensively in many manufacturing fields including automobiles, refrigerators, electrical equipment, household appliances, aeronautical, etc. A proprietary fastening known as "Lok-Skru" manufactured by the Dill Mfg. Co. 

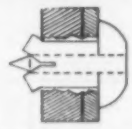
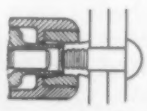
(Continued on next page)

atmospheric conditions. Threaded aluminum fasteners are easily removed and reassembled without danger of rust-binding and subsequent breakage. Where maximum strength and stiffness is required in an aluminum fastening device, 24S-T4 Alclad is usually used; for general use, where some deformation under load is desirable, 2S-H18 is used.

The non-toxic qualities of aluminum and its alloys are particularly important in cases where the metal is in contact with foods, beverages or drugs, and its chemical resistance to certain acids, alkalies, yeasts, gums or resins is important for many specialized applications.

Since aluminum fasteners weigh only ⅓ as much as comparable steel, brass or nickel types, their inherent lightness and great strength have resulted in widespread aeronautical use. As the stressed-skin type of aircraft construction has developed, the use of cold-driven aluminum alloy rivets in the smaller sizes has increased considerably. The duraluminum type of alloy is frequently

Table VI—Types of Rivets—(Continued)

Type of Rivet	Materials from which usually made	Advantages	Limitations	Applications
Blind Rivets	56S hard aluminum alloy for sleeve, 24SRT aluminum alloy for pin	A two-part, preassembled blind rivet consisting of a hollow sleeve having a head with a conical recess and locking collar at the outer end; and a pin which is pressed into the sleeve. Rivet is available with either countersunk or brazier head. During initial part of driving operation, special riveting gun pulls extruding angle and land of pin through sleeve, expanding sleeve to fill the hole. After sleeve is expanded, sleeve is squeezed between head of pin and nose of rivet gun to form blind head. Head of pin upsets sleeve end and forms a bulbed head. With blind head formed, gun forces locking collar at outer end of sleeve into conical space between recess in head and locking groove in pin. Finally, pin is broken off in tension at breakneck groove substantially flush with projecting head of sleeve.	Special tool required for installation. Cannot be reused. Finished rivet pin break must be ground flat for a smooth, flush appearance.	Used in many manufacturing fields such as automobile, refrigeration, electrical equipment, appliances, aeronautical, etc. A proprietary fastening manufactured by the Huck Mfg. Co. 
	Carbon steel, brass, copper	A blind rivet designed on the principle of the expansion bolt and consisting of a slotted and headed form through which a hole is longitudinally bored part way. A pointed pin is driven through this hole. As point of pin reaches bottom of bored hole, it forces the legs of the rivet apart, thus clinching the joined sheets. No special tools are required.	Limited strength achieved. Cannot be reused.	Used primarily in assembling electrical switchboards, and for fastening fixtures, brackets, bins, etc. A proprietary fastening manufactured by the Brush Nail Expansion Bolt Co. 
	High carbon steel, low carbon steel, brass	A blind fastening designed to hold two or more thicknesses of material firmly together. Available in several different styles. Three flared prongs on style shown are compressed as rivet is pushed through pre-drilled hole. Prongs spread in hole and flared tips securely hold material when emerged on blind side. No special tools are required for installation.	Limited holding strength is achieved.	Used primarily for assembling and installing lightly-stressed components such as mats, panels, trim, moldings, etc., in automotive and aeronautical industries. A proprietary fastening known as "Trimount" manufactured by United-Carr Fastener Corp. 
Collar Rivets	Steel	A two-piece rivet available with 100 deg. flat countersunk or flat binding head and consisting of headed rivet pin and circular collar. No washers or shims are required because collar adjusts itself when driven. Rivet can be driven from pin or collar end.	Special driving tool required.	Used extensively in many manufacturing fields such as automotive, aeronautical, refrigeration, electrical equipment, etc. A proprietary fastening known as "Hi Shear" and manufactured by the Pheoll Mfg. Co. 
	24ST and 75ST aluminum alloy, carbon steel, high-strength alloy steel	A two-piece fastener consisting of a headed pin and a locking collar. Pin is partially serrated with grooves for jaws of driving gun, and also serrated with grooves for locking collar. After pin is inserted in work, collar is slipped on and gun applied. Gun jaws engage pull grooves in end of pin. Initial pull of gun squeezes work together between collar and head of pin. Hole is filled as pin is drawn into a press fit in hole. Increased pull on pin forces gun anvil over collar, swaging collar into serrated locking grooves on upper shank of pin. Further increase in pull breaks off pin at breakneck groove approximately flush with collar. Pins are available in a wide variety of heads.	Special tool required for installation. Cannot be reused. Finished rivet pin break must be ground flat for a smooth, flush appearance.	Used extensively in many manufacturing fields such as automotive, aeronautical, refrigeration, electrical equipment, etc. A proprietary fastening manufactured by the Huck Mfg. Co. 
Solid Rivets	Carbon steel, stainless steel, brass, copper, zinc alloy, Monel, silicon bronze, nickel alloy, aluminum, naval bronze	Available in wide variety of head styles: round, flat, 90 deg. flat countersunk, tinner, cone, pan, oval, acorn, etc. No special tools are required for heading operations since ends of rivets are merely peened over to clinch the sheets. Washers are sometimes used under the peened ends to protect the work surface and to provide a better bearing surface.	Peened end of rivet subjected to severe stresses in heading operation. Rivets cannot be reused. Considerable care required to assure liquid-tight joint.	Widely used in many manufacturing fields and construction fields.
Split Rivets	Carbon steel, stainless steel, brass, copper, zinc alloy, Monel, silicon bronze, nickel alloy, aluminum, naval bronze	Available in wide variety of head styles: round, flat, 90 deg. countersunk, cone, pan, oval, acorn, etc. No special tools are required since heading usually consists of merely bending the two prongs or legs outward to clinch the sheets. Washers are sometimes used under the bent prongs to protect the work surface from gouging or marring by the prongs and to provide a better bearing surface.	Bent prongs or legs of rivet subject to severe stresses in bending operation. Limited strength of joint. Rivets cannot be reused. Liquid-tight joints cannot be obtained.	Widely used in many manufacturing fields, particularly where a low-cost, and quickly-made joint is not required to withstand heavy loads.
Tubular Rivets	Carbon steel, stainless steel, brass, copper, zinc alloy, Monel, silicon bronze, nickel alloy, aluminum, naval bronze	Available in wide variety of head styles: round, flat, 90 deg. countersunk, cone, pan, oval, etc. No special tools are required since heading usually consists of merely spinning, rolling, peening or flaring the hollow end of the rivet over to clinch the sheets. Washers are sometimes used under the headed end to protect the work surface from gouging or marring and to provide a better bearing surface.	Rolled edge of rivet subject to severe stresses in bending operation. Limited strength of joint. Rivets cannot be reused. Liquid-tight joints difficult to obtain.	Widely used in many manufacturing fields where a low-cost and quickly-made joint is not required to withstand heavy loads.

used, being driven in the soft condition that exists following solution heat treatment. Subsequent precipitation hardening of these rivets results in full mechanical properties and corrosion resistance. The difficulty formerly associated with driving such rivets shortly after solution heat treatment has been overcome by use of refrigeration to delay age hardening.

Aluminum alloys containing magnesium are used for fastenings in many aircraft components. These alloys possess considerable work hardening capacity and thus the fastenings develop reasonably high strengths after installation.

Magnesium alloys are usually joined with fastenings produced from an aluminum alloy containing approximately 5% magnesium. Such fastenings are installed cold, and the difference in potential between them and the magnesium components is so small that little, if any, corrosion results. Pure aluminum fastenings are sometimes used in this material, but their low shear strength

Table VII—Types of Staples

Type of Staple	Materials from which usually made	Advantages	Limitations	Applications
Flat, or "Square" Type Stitch	Steel wire, 18 gage or less.	Joins metal to metal, or metal to fabrics, rubber, wood, asbestos, plastics, fiber, etc., without requiring backing strip to prevent pulling through. Can be used to produce "sandwiches" of various materials between two sheets of metal. Maximum strength obtained by firm clinching pressure. Sharp 90 deg. angles at all four corners produce full "line" contact on both sides of joined work. Positive pressure provided between joined parts; amount of pressure being adjustable over wide limits by variable clinching action and die pressure during stitching. High production rates assured at low cost.	Definite limitation on thicknesses of stock that can be joined. Flush joints cannot be produced. Considerable difficulty encountered in disassembly operations. A certain amount of inaccessibility in tight corners and sharp radii. Difficulty in obtaining airtight seams. A slight amount of distortion produced, especially when stitches fall close to edge of material. Definite limitation on strength of joint.	Widely used to fasten lightly loaded and lightly stressed structures in automotive, aeronautical, and appliance fields such as fastening grillework, shielding, housings, insulation assemblies, etc.
Curved, or "Round" Type Stitch	Steel wire, 18 gage or less.	Same general advantages as those indicated for flat, or "square" type stitch: High production rates assured; extreme versatility; fast inspection; low cost assembly; etc. But does not achieve same degree of positive clinching pressure between joined parts, nor same full "line" contact with surface of work on under side.	Results in a "springy" joint with weak pressure because grip is limited to point contact only. Even greater difficulty in obtaining airtight seams than with flat type. Greater distortion and limitation on strength of joint. Flush joints cannot be produced. Definite limitation on thickness of stock that can be joined. Vibration causes "knee" of stitch to dig into work surface on curved side; this decreases fastener strength and allows play in joint. Not satisfactory for stressed applications.	Widely used to fasten lightly-loaded and comparatively non-stressed structures in automotive, aeronautical, and appliance fields such as fastening insulation stripping, radiator shells, instrument panel assemblies, housings, etc.

effectively limits widespread use in this connection.

Nickel and nickel-base alloys are used for fastenings where high mechanical properties are needed to withstand corrosive liquids or gases, extremely high or low temperatures, shock loading, or other similarly destructive service conditions. These materials are distinguished by their combination of strength, toughness and resistance to corrosion.

The nickel used for fastening devices is usually the commercially pure grade. Fastenings of this metal are especially recommended for food processing, chemical and pharmaceutical applications where the purity, color or flavor of the product must be protected against metallic contamination. The mechanical properties of nickel are similar to those mild steel, and it retains its strength well at high temperatures. Its ductility and toughness, as well as its strength, are likewise retained at extremely low temperatures.

Inconel is used for fastenings primarily where high strength and resistance to oxidation up to 2000 F must be maintained.

Monel is the nickel alloy most commonly used for fastenings where greater strength, hardness, toughness and corrosion resistance are required than is ordinarily found in mild steel. Monel is widely used in marine construction, chemical equipment, etc. where such characteristics are needed to withstand severe service.

K-Monel is similar to Monel in composition and corrosion resistance, but has an added advantage in that it can be hardened by heat treatment to obtain strength and hardness values corresponding to those of heat-treated alloy steels.

Copper is an excellent cold-flowing material and is used extensively for fasteners that do not require high tensile strength. It has a high resistance to atmospheric corrosion and stress corrosion, and provides an excellent and durable surface if subsequent plating is desired. To enhance or achieve certain characteristics that are either lacking or present only in a small degree, other metals are commonly alloyed with the copper to produce materials for specified applications.

Brass is the most common of the alloys of copper. It is relatively inexpensive; is easily worked into any shape or form; is strong and tough; and is resistant to corrosion. For most common fastening applications, two brass alloys are customarily used: free-machining Yellow Brass and ordinary Yellow Brass. The free-machining grade contains approximately 3% lead which imparts the free-machining qualities. Nuts, set screws, studs, and other milled fasteners are commonly made from this alloy. The ordinary grade of Yellow Brass is commonly used for bolts and rivets. Both grades have an average tensile strength of 65,000 psi., and both will take and hold a plated coating exceptionally well.

Bronzes are used for many types of fastening devices where high tensile strength, good conductivity, easy workability, and corrosion resistant qualities are desired. Combinations of copper with phosphorus, manganese, tin, lead, silicon, etc., in varying degrees produce a variety of bronze alloys from which virtually all characteristic requirements can be met. Several of these are of a proprietary nature, particularly in the case of the copper-silicon alloys. These bronzes have a tensile strength approximately equal to that of mild steel and offer a greater resistance to a wider variety of corroding agents than pure copper. Silicon bronze fastenings are used extensively for pole line hardware, marine equipment, sewage treatment and water reservoir installations as they resist "season cracking" due to seasonal temperature change and resist atmospheric corrosion. High silicon (2.7 to 3.75%) bronze is used primarily in the manufacture of hot forged machine bolts, carriage bolts, washers, lag screws and large size rivets. Low silicon bronze is used for cold-headed bolts, machine screws and rivets as well as for certain sizes of nuts.

Naval bronze and naval brass are one and the same alloy, the apparent duplication being caused by the fact that naval bronze is the commercial name and naval brass is the name given it by the Navy Department. This alloy is an improved form of Muntz Metal and contains a small percentage of tin. It possesses the necessary resiliency and toughness to withstand sudden shock and strain caused by impact, and is used primarily for fastenings exposed to rough, corrosive service conditions.

Manganese bronze is another copper, zinc alloy of the Muntz Metal type which has been improved in physical properties and corrosion resistance by the addition of small amounts of manganese, tin and iron. Tin imparts hardness and strength and increases corrosion resistance by reducing dezincification. Iron increases hardness and strength and acts as a grain growth inhibitor. Manganese also refines grain structure, increases strength, and improves working properties. Manganese bronze fastenings are primarily used where great strength plus incorrodibility are required. It is used in place of naval bronze where higher physical strength is necessary.

Phosphor bronze is the most important of the copper-tin alloys, and is composed basically of these two metals with the oxides eliminated through the addition of phosphorous as a deoxidizing agent. By means of close alloying control, fine-grained, homogenous metals are produced that possess high tensile strength, high elastic limit, high resistance to fatigue, high corrosion resistance, high resistance to wear, and low coefficient of friction. By virtue of these qualities, phosphor bronze is especially suitable for use in fasteners that are subjected to excessive strain or vibration. It can be worked either hot or cold with minor alloying adjustments and is used chiefly for large-size bolts, nuts and studs.

Acknowledgment

Acknowledgment is made for the assistance given in the preparation of this manual by the following organizations:

Acme Steel Co., Chicago, Ill.
Allmetal Screw Products Co., New York, N. Y.
Aluminum Co. of America, Edgewater, N. J.
American Institute of Bolt, Nut & Rivet Mfrs., Cleveland, Ohio
An-Cor-Lox Div., Laminated Shim Co., Glenbrook, Conn.
Bethlehem Steel Co., Bethlehem, Pa.
B. F. Goodrich Co., Akron, Ohio
Boots Aircraft Nut Corp., Stamford, Conn.
Bostitch, Inc., Westerly, R. I.
Bristol Co., Waterbury, Conn.
Brush Nail Expansion Bolt Co., Greenwich, Conn.
Central Screw Co., Chicago, Ill.
Cherry Rivet Co., Los Angeles, Calif.
Corbin Screw Div., American Hardware Corp., New Britain, Conn.
Diamond Head Screw Corp., Los Angeles, Calif.
Dill Mfg. Co., Cleveland, Ohio
Dzus Fastener Co., Inc., Babylon, N. Y.
Edwin B. Stimpson Co., Brooklyn, N. Y.
E. I. du Pont de Nemours & Co., Wilmington, Del.
Elastic Stop Nut Corp. of America, Union, N. J.
Ferry Cap & Set Screw Co., Cleveland, Ohio
George K. Garrett Co., Philadelphia, Pa.
Greis Reproducer Corp., New York, N. Y.
Groov-Pin Corp., Union City, N. J.
H. M. Harper Co., Morton Grove, Ill.
Holo-Krome Screw Corp., Hartford, Conn.
Holub Industries, Inc., Sycamore, Ill.
Huck Mfg. Co., Detroit, Mich.
Interlock Corp., Newark, N. J.
International Nickel Co., Inc., New York, N. Y.
Lamson & Sessions Co., Cleveland, Ohio
Lock Thread Corp., Detroit, Mich.
Nelson Stud Welding Div., Morton-Gregory Corp., Cleveland, Ohio
Nylock Corp., New York, N. Y.
Oliver Iron & Steel Corp., Pittsburgh, Pa.
Palnut Co., Irvington, N. J.
Pheoll Mfg. Co., Chicago, Ill.
Prestole Corp., Toledo, Ohio
Reliance Div., Eaton Mfg. Co., Massillon, Ohio
Reynolds Metals Co., Richmond, Va.
Republic Steel Corp., Cleveland, Ohio
Scovill Mfg. Co., Waterbury, Conn.
Shakeproof, Inc., Chicago, Ill.
Simmons Fastener Corp., Albany, N. Y.
Stemco Corp., Rocky River, Ohio
Stover Lock Nut & Machinery Corp., Easton, Pa.
Tinnerman Products, Inc., Cleveland, Ohio
United-Carr Fastener Corp., Cambridge, Mass.

Materials Engineering File Facts

NUMBER 177
July, 1949

Strengths of Various Adhesive-Adherend Combinations

The strength properties of the adhesive-adherend combinations given below are based on the results of an investigation made by the National Bureau of Standards for the National Advisory Committee for Aeronautics. The choice of adherends and adhesives for the work was governed by a desire to study many different chemical types of bonds.

Table I lists and describes the nature of the adhesives and gives the processing data. Table II gives the strength data. The shear strengths given are based on tests of double-lap joint specimens. The impact strengths are based on tests of single lap joint specimens. All specimens were conditioned for a minimum period of seven days at a temperature of 77 F and 50% relative humidity and were tested under these conditions.

The report from which this data are taken is "Comparative Strengths of Some Adhesive-Adherend Systems," by N. J. DeLollis, Nancy Rucker and J. E. Wier.

Table 1—Description of Adhesives and Processing Data

Adhesive	Type	Manufacturer	Formulation (Parts by Weight)	Drying Conditions		Bonding Conditions		
				Time (Hr.)	Temperature (F)	Time (Hr.)	Temperature (F)	Pressure (Psi.)
Cellulose Nitrate	20-sec. viscosity	Hercules Powder Co.	Cellulose nitrate 10 Ethyl acetate 85 Camphor 5	20	77	2	248	150-200
Polyvinyl Acetate	AYAF	Carbide & Carbon Chemicals Corp.	Polyvinyl acetate 20 Acetone 80	2 2	122 176	2	248	3
Resorcinol Resin	Penacolite G1131	Pennsylvania Coal Products Co.	Resorcinol resin 5 Catalyst 1	0.25	77	20	149	3
Casein	Reg. B 1	Casein Co. of America	Casein 100 Water 300 (soak for 15 min.) Calcium hydroxide 30 Sodium fluoride 5.8 Sodium phosphate 17.4 ($12\ H_2O$)	0.5	77	20	77	3
Gum Arabic	GU 2	Arabol Manufacturing Co.	Gum arabic 50 Water 50 Thymol 2.5	0.5	77	20	77	3
Rubber	Smoked sheet	—	Rubber 100 Benzene 400 Zinc oxide 5 Sulfur 4	1	77	7	284	150-200
Neoprene	GN	E. I. du Pont de Nemours & Co., Inc.	Neoprene 100 Ethyl acetate 200 Zinc oxide 5 Magnesium oxide 4	1	77	3.5	248	150-200

(Continued on page 85)

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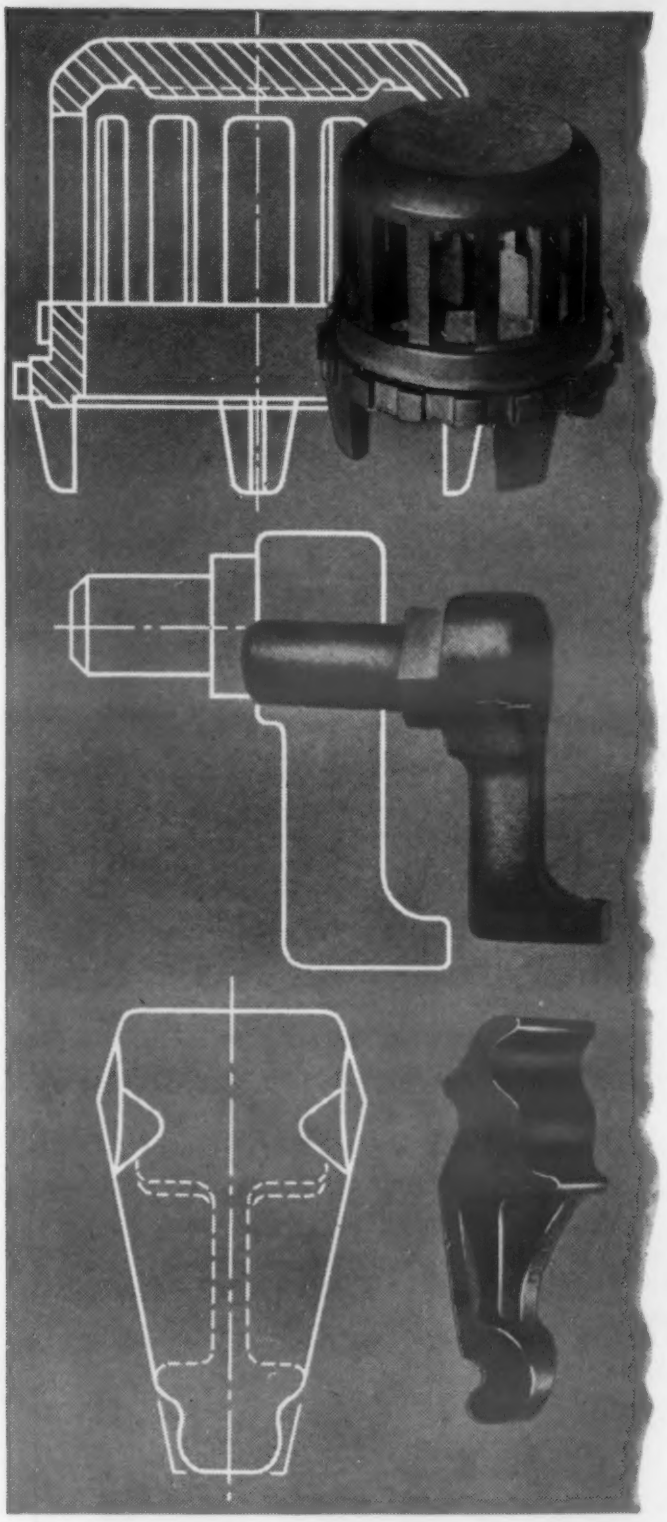
Table II—Strength Data for Various Adhesive-Adherend Combinations

Adherend	Adhesive						
	Cellulose Nitrate	Polyvinyl Acetate	Resorcinol Resin	Casein	Gum Arabic	Rubber	Neoprene
STAINLESS STEEL							
Shear Strength, (Psi.)	1580	2960	0	190	130	270	90
Tensile Adhesion Strength, (Psi.)	2180	3600	0	510	110	260	170
ALUMINUM ALLOY							
Shear Strength, (Psi.)	1360	3560	0	120	330	250	130
Tensile Adhesion Strength, (Psi.)	1500	3270	0	110	110	390	290
Impact Strength, Edgewise, Ft.-Lb.	—	0.210	—	—	—	—	0.985
Impact Strength, Flatwise, Ft.-Lb.	—	0.106	—	—	—	—	0.056
PAPER-PHENOLIC LAMINATE							
Shear Strength, (Psi.)	1680	2480	1370	1030	440	130	250
Tensile Adhesion Strength, (Psi.)	860	1060	830	690	630	160	170
GLASS							
Shear Strength, (Psi.)	1680	2310	0	29	210	43	100
Tensile Adhesion Strength, (Psi.)	1040	2430	0	0	260	34	90
BIRCH WOOD							
Shear Strength, (Psi.)	1390	1990	1940	1660	630	160	180
Tensile Adhesion Strength, (Psi.)	1100	960	1180	1020	400	170	340
Impact Strength, Edgewise, Ft.-Lb.	—	0.207	0.397	—	0.112	0.590	—
Impact Strength, Flatwise, Ft.-Lb.	—	0.126	0.079	—	0.023	0.171	—
HARD RUBBER							
Shear Strength, (Psi.)	1000	630	590	150	240	190	230
Tensile Adhesion Strength, (Psi.)	590	400	1340	130	320	130	240

Intricate Shapes at Reasonable Cost

with HAYNES Trade-Mark *Precision Castings*



Assembly costs are eliminated by producing this stainless steel valve cage by the precision investment-casting process. Formerly made in two pieces and joined together, the cage is now produced as a single, integral casting.

This screw cycle controller is investment-cast from a one-piece wax pattern. The part was formerly made by brazing together two individual pieces machined from bar stock.

This HAYNES STELLITE alloy sealing segment was redesigned in order to avoid warpage and distortion. Although the ribbed section —which was formerly solid —adds to the intricacy of the part, it causes no fabrication difficulties when produced by HAYNES precision investment casting.

The alloys that are available as HAYNES precision investment castings—such as HAYNES STELLITE, HASTELLOY, and MULTIMET alloys, and certain stainless steels—are strong materials that resist the most severe abrasion, heat, and corrosion. But because of their unusual properties, these alloys are often difficult and costly to fabricate by conventional methods. The precision investment-casting process, however, is a practical method of producing parts from these materials. And it makes possible the liberal use of such design features as thin edges, fillets, irregular holes, and intricate contours.

If you need production quantities of an intricate part cast to close tolerances, investigate HAYNES precision investment castings. You will find that they are smooth and uniform—and held to such close dimensional standards that several finishing operations might be eliminated. Our engineers will co-operate with you in designing new parts to be precision investment-cast, or in re-designing parts for greater efficiency and increased economy. For more information, write for the booklet "HAYNES Precision Castings."

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MATERIALS & METHODS DIGEST

A selective condensation of articles — presenting new developments and ideas in materials and their processing — from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Effect of Sulfur on the Quality of Steels

Despite the fact that the problem has long existed, the effect of sulfur on the quality and end uses of steel products has never been clearly resolved. M. Tenenbaum in his paper "Effect of Sulphur on Quality and End Uses of Steel Products," presented before the general meeting of the *American Iron & Steel Institute*, May, 1949, has surveyed various steel products with respect to sulfur limits needed to meet quality requirements and has indicated the manner in which the influence of sulfur is felt. In the evaluation of product quality, consideration was given to both rolling surface requirements and to the specific properties demanded for each end use.

The data on which the paper is based were obtained from 26 steel plants. A table is given showing the average maximum sulfur requirement for each grade and product considered, together with the property most generally conceded to be responsible for this sulfur limit and the average maximum sulfur specified to steelmaking furnaces. With the exception of drawing quality cold rolled sheets, welding quality rod and a single special high tensile grade, the maximum sulfurs on the plain carbon grades required to meet surface and rolling requirements within the plant itself are lower than the values needed for the various end uses.

From other data obtained, it appears that small variations in sulfur content can and probably do exert a significant effect on product quality. The small variations in specified values often can hardly be justified on the basis of the apparently limited information available regarding the effect of sulfur on quality. The confused situation in which the effect of small sulfur variations does not seem satisfactorily defined is particularly pronounced in the case of the commercially important steels for deep drawing applications. Unquestionably, further work is necessary to establish the effect of sulfur on hardness, ductility and product performance of the deep drawing steels. Because of the high cost associated with the elimination of a few thousandths of a per cent of sulfur as the specified limit for deep drawing steels is approached, logical and reliable data should be sought on which to establish specification. Such reliable information could then be used either to allow some relaxation of the present rigid sulfur limits or to justify the higher steelmaking problems that would be involved in meeting even lower sulfur limits.

The data relating sulfur to quality variables and the number of steels surveyed are obviously limited. The data can be used, however, to demonstrate the general nature of present knowledge regarding this pertinent and practical problem, and also can serve as a basis for directing future experimental investigations into the true role of sulfur in the metallurgy of steel.

Electrolytic Polishing Studied for Improvement of Surface Properties

In Europe considerable study is being made of the capabilities, limitations and possible uses of electrolytic polishing. The possibilities of using electrolytic polishing to obtain highly finished precision parts are explored by P. Michel in *Revue de Métallurgie* (French), Jan., 1949. At first glance, electrolytic polishing looked promising as an improvement over superfinishing. It was thought that the highly polished surface would be beneficial from the standpoints of friction and fatigue strength.

A series of tests was made on piston pins. Despite the unusually simple shape, a long empirical investigation was required to determine polishing conditions that would give a strictly cylindrical piece. A combination of conducting sleeves and non-conducting screens finally gave the desired results. These fixtures, however, are not simple, and in mass production considerable set-up time would be needed. Since the metallic parts of the fixtures in electrical contact with the anode dissolve during polishing, frequent replacements would be required. On the other hand, the results are perfectly reproducible.

The electrolytically polished surface was superior to honed and ground surfaces in respect to dry friction, but no difference was observed when a lubricant was used. The fatigue strength was about the same for electrolytically polished and for ground specimens. Therefore, electrolytic polishing is no sure guarantee of an improvement in physical and mechanical properties.

The author concludes that the use of electrolytic polishing for finishing precision parts seems to have only limited application. In the discussion, however, the opinion was expressed that there are modern industrial polishing baths (no further description) that give highly satisfactory results and that do not require the complicated fixtures found necessary in the author's perchloric—acetic acid solution.

Additional French work on electrolytic polishing was reported by R. Mondon in *Revue de Métallurgie* (French), Dec., 1948. The particular aim of this work was to determine whether electrolytic polishing would improve the friction properties and wear resistance of engine parts.

Four steels were tested after electrolytic and mechanical polishing: (1) hardened bearing steel; (2) a hardened, carburized nickel-chromium-molybdenum steel; (3) a medium carbon nickel-chromium-molybdenum steel at two hardness levels; and (4) a nitrided chromium-molybdenum steel. The first series of tests was made under conditions of alternating movement against a lubricated tin bronze. The electrolytic polishing gave the most favorable results, both in regard to friction and wear. The least improvement was noted with the nitrided steel. The hardness of the steel had no apparent effect on the coefficient of friction or the wear in the 3-min. tests.

The second series of tests was made with the same steels rotated against a standard steel under various conditions of lubrication. The results were evaluated on the basis of the friction at the moment of starting and the "factor of safety" (the difference between the friction couple at

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the moment of starting and that at the finish of the test divided by the former.) The classifications on the two bases were not in exact agreement, but the electrolytically polished steels had a slight superiority in both cases (10 to 15% on the first basis and 30% on the second).

It is not clear whether the advantages produced by electrolytic polishing are the results of its effect on the surface finish or of a modification of the structure of the superficial layers.

The Trend Toward Low Temperature Porcelain Enamels

One of the most radical changes that promises to modify the present concept of porcelain enamels is the trend toward lower-firing enamels, according to an article by E. J. Kelley and G. E. Miller in *The Enamelist*, Spring, 1949. While they are not necessarily intended as replacements for the corresponding 1500 F enamels, they make possible the enameling of objects and materials heretofore not feasible using temperatures as low as 1300 F.

At the outset it was thought that satisfactory bond could not be developed without the use of special steels. However, at the present time many dark-color, low-fire finishes are commercially practical with nickel flashed, cold-rolled steel.

In the field of titanium enamels there is now a 1450 F enamel which is equal to the standard-fire enamels and has been used successfully on refrigerator liners. It has also been used successfully as overspray over low temperature zircon. Also on the market now are zircon enamels similar in properties to conventional zircon enamels but with a 1450 F maturing temperature. They have been used in production with equal success over both conventional high-speed ground coat and a 1450 F ground coat.

In the range of 1300 to 1350 F satisfactory ground coats are also available. A nickel dip is necessary at present to obtain a good bond. The surface is good and cover coats can be applied over them satisfactorily.

Developed primarily for architectural use are low temperature, acid-resistant semi-matte finishes for both light and dark colors. Another widely used low temperature, direct-on-steel finish is a low-opacity antimony enamel. Most satisfactory results with this finish are obtained when it is used over specially treated steel. When used on these steels the bond is excellent and all dark browns and grays can be produced.

One big potential use for low tempera-

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ture enamels is on aluminum. The range of articles made of aluminum could be further increased and their performance further improved if it were possible to apply a tough, durable and abrasion resistant surface coating. The conventional vitreous enamels used on iron and steel, however, have firing temperature too near the melting point of aluminum. A critical study of the new development of low melting point enamels for aluminum has been made by J. C. Bailey and M. E. Whitaker in *Light Metals* (English), Mar. 1949.

Most of the work has been concentrated on lowering the melting point of existing enamels by the addition of lead compounds, but a leadless glaze fusing at 1020 F has also been evolved. Since some of the enamels withstand water quenching from the firing temperature, it is possible that their application might be combined with the heat treatment of hardenable aluminum alloys.

Tests on seven enamels (one leadless) showed that all had much better resistance to thermal shock, heat and mechanical damage than stoved paints. The adhesion was excellent and their resistance to mechanical damage was superior to that of the vitreous enamels used on steel; their hardness and abrasion resistance were rather less, although considerably greater than that of stoved paints. Chemical durability and resistance to water, moisture and weathering were not very good. Resistance to acid and alkali was usually poor except for one of the lead-base enamels. Pigmentation of the lead-base enamels adversely affected some properties. The lead solubility of the lead-base enamels would preclude their use in contact with foodstuffs.

A subsequent commercial appraisal indicates that even at this early stage there is an immediate, if limited, field for their application. The leadless glaze is likely to attract special attention because of its greater hardness and resistance to moisture and abrasion; it should find many uses. Vitreous enamelled cast iron and steel must in the future reckon with direct competition from vitreous enamelled aluminum.

Aluminum Clad Steel in Germany

In Germany prior to the war, aluminum clad steel was produced in appreciable quantities, amounting to about 500 tons per month, according to an article appearing in *Metallurgia* (English), May, 1949. The material was marketed under the name of Feran and was used largely for such products as diaphragms for telephones, windings for flexible piping, and bands

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for electric cables used in heating equipment.

The method of manufacture briefly consists of a mechanical cladding operation followed by a thermal treatment so as to alloy the steel and aluminum in an intimate manner. The steel used was of deep drawing quality with the following composition: 0.06 carbon, 0.04 sulfur, 0.04 phosphorus, 0.6% manganese, and traces of silicon. The aluminum used contained from 0.6 to 1% silicon and 0.35% iron. The aluminum was cold rolled down to about 0.008 in., heat treated in coiled bands, rough brushed and then coiled on special holders. It was then roll-laminated with the steel.

The lamination must be done with the maximum possible elongation, and reduction in one pass is at least a minimum of 40%. The temperature required for a good lamination ranged from about 210 to 390 F. After the laminating, the material is further cold rolled to the final thickness. The laminated strip is then heat treated at a temperature varying between 995 and 1020 F.

Current Developments in Metals Discussed at Regional A. I. M. E. Conference

The Institute of Metals Division of the *American Institute of Mining & Metallurgical Engineers* held their third annual regional conference in Springfield, Mass., April 22 and 23. A number of important papers of current interest were presented.

Brazing with Gaseous Fluxes

A. P. Edson and D. G. Paquette delivered a paper on "Gaseous Fluxes for Brazing Steel." The difficulty encountered in removing liquid fluxes from the work, plus the fact they were more or less corrosive to the base metal, lead the authors to the development of gaseous fluxes. They found that hydrogen chloride vapor will function, but outside the laboratory the traces of moisture present permit corrosion of the steel being joined. Although hydrogen fluoride would work, ammonium fluoride, bifluoride and polyfluorides were simpler to handle and produced comparable results. Ammonium fluoborate proved to have superior fluxing activity while boron trifluoride was the most satisfactory gaseous flux reported. It was less toxic than the fluorides, available in high pressure cylinders, did not sublime and clog exhaust lines from the brazing chamber, did not attack

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the steel surface, fluxed more effectively, and produced the best joints. Although excellent for certain applications, gaseous fluxing is not a cure-all; it is relatively slow, extremely sensitive to contamination, and more expensive.

Bonding Aluminum to Steel

The combination of aluminum on steel is advantageous in many applications where special performance requirements must be met. One of the critical factors is, of course, the bonding strength, and V. W. Cooke and A. Levy discussed this in their paper "Solid Phase Bonding of Aluminum to Steel." They pointed out that one of the chief precautions to a successful bond was to avoid a heavy oxide coating on the ferrous material. This could be done by using stainless steel or chromium plating the low alloy steels. After bonding, a full solution treatment for the aluminum alloy is not permitted since this combination of time and temperature permitted enough diffusion to build up a sufficiently thick intermetallic compound layer to be brittle. Bond strengths of from 20,000 to 50,000 psi. were possible, and bonding could be accomplished at as low a temperature as 550 F where little upsetting under the pressures used was noted.

Titanium

The current high interest in titanium metal was reflected by the paper "Metallography and Properties of Commercially Pure Titanium," by W. L. Finlay and E. L. Wemple. Two interesting facts were noted: (1) that titanium changes from hexagonal-close-packed to body-centered cubic above 1620 F, and (2) that titanium twins mechanically when deformed at room temperature. The latter required care in removing the affected surface immediately below the scratches produced in the early metallographic polishing steps before final polishing.

Titanium is intermediate between aluminum alloys and stainless steel in specific gravity, about equal to them on a strength-weight ratio, has a higher melting point than either, and has twice the annealed yield strength of 18:8. The paper listed possible applications for titanium as follows: airframe skins and structures where intermediate temperatures or corrosion problems are encountered, and aircraft power plants where temperatures between 300 F and 800 F are involved and naval or marine applications combining superior corrosion resistance and light weight; industrial equipment and other applications in which a combination of light weight, corrosion resistance, high strength and intermediate temperature properties are required.

Alodizing Reynolds *Lifetime* Aluminum sheets, building siding, and refrigerator crisper pans at the Louisville Plant of the Reynolds Metals Company.

Alodizing Reynolds *Lifetime* Aluminum coiled sheet at the McCook Illinois Plant of the Reynolds Metals Company.

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Sintered Platinum Powder Parts with Improved Properties

In the past no essential difference has been noted between the physical properties of sintered pure platinum and cast pure platinum. In a paper in the *Journal of the Institute of Metals* (English), Mar. 1949, A. B. Middleton, L. B. Pfeil and E. C. Rhodes show that there are definite differences in favor of the sintered pure platinum.

By sintering and hot working a fine powder compact of pure platinum at a temperature considerably below its melting point, and then following this by severe cold drawing to wire, the fibrous structure of the wire was found to remain, even when heated to temperatures well above the recrystallization temperature of wire produced from melted, cast, and similarly worked pure platinum.

This increased stability of the fibrous structure in sintered platinum wire is due to a small amount of suitably dispersed porosity, which has the effect of hindering recrystallization. The sintered platinum wire has greater resistance to elongation under tension at high temperature, and greater resistance to intergranular corrosion, than wire from melted and cast platinum.

There are many practical applications where a metal such as this containing suitable dispersed porosity is desirable and where improved mechanical properties and resistance to deterioration at high temperatures are also required. Examples are the elements of resistance-heated furnaces, electrodes for spark plugs, thermocouples, valve electrodes, and excess-temperature fuses. In airplane engines, it is advantageous that the spark plug electrodes made from platinum alloys retain the fibrous structures originally present in the cold-drawn wire in order to minimize the embrittlement produced by intergranular penetration of lead from the fuel.

Corrosion Resistance of Titanium

Sea-water test data obtained on the new metal titanium, by Remington Arms Co., Inc., shows that it is practically unaffected by exposure to sea-water or marine atmosphere. The tests were conducted on a comparative basis with other common metals such as stainless steel and aluminum. None of these standard metals approached the corrosion resistant properties of titanium in sea water.

The sea-water corrosion resistance of this

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new material, possessing a high strength-to-weight ratio is, naturally, of interest to aircraft, marine and allied construction industries. Moreover, the ability to resist corrosion by sea-water is a desirable property for any metallic material of construction.

In these tests the specimens are frequently wetted by salt mist and spray. After 120 days' exposure, titanium appeared unaffected although other comparable metals developed corrosion and rust.

In addition to its resistance to sea-water corrosion, titanium indicates very low corrosion rates in a number of reagents normally considered corrosive to most metals. Wet chlorine gas, hot chromic acid and hot ferric chloride solutions are not corrosive to titanium. Complete immunity from corrosion by water-saturated chlorine gas and chlorine saturated water is believed to be one of titanium's most outstanding properties. Tests indicate titanium should be an excellent material for handling chlorine gas.

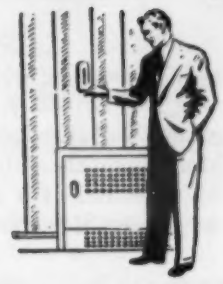
New Method for Deposition of Metals on Aluminum

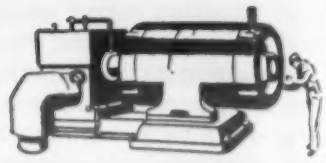
Electroplated coatings on aluminum have assumed an important place among the finishes for this metal, because the light weight and low cost of aluminum are combined with the specific desirable properties of the plated coating. A new process has now been developed for depositing zinc, cadmium and tin by chemical displacement upon aluminum. It is described by S. Heiman in a paper appearing in the *Journal of the Electrochemical Society*, May, 1949.

The immersion deposits have sound structure and such a high degree of adhesion to the aluminum that they can be used as a base for subsequent electrodeposition of other metals. The bond between the zinc immersion deposit and the aluminum, for example, was found to be greater than the cohesive strength of the aluminum base metal.

The solutions used in the process consist of the metal sulfite, hydrofluoric acid, or a fluoride salt and, in specific cases, organic addition agents. For example, the preferred composition and conditions for depositing zinc by immersion are as follows: zinc sulfate, 5N; hydrofluoric acid, 1N; time of dip, 30 to 60 sec.; temperature, 77 F.

The new procedure involving the zinc film appears to be at least equal in quality and simplicity to the zincate process. Also, the immersion deposits of tin have better adhesion to aluminum than those obtained by the commercial stannate process.





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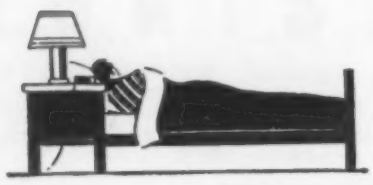

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New Materials and Equipment

New Design in Muffle Furnaces Improves Performance

A new design in muffle furnaces has been announced by the *Hevi Duty Electric Co.*, Milwaukee 1, Wis. The furnaces have been designed primarily for general laboratory requirements, such as drying of precipitates, ash determinations, fusions, ignitions, heating metals and alloys, enameling and ceramic firing, heat treating, and for general experimental work.

Departing from the usual rectangular shape, the new furnace is housed in a cylindrical shell mounted on a pyramidal type base with practically line contact between them, thus allowing free circulation of air and eliminating trapped heat in the base.

Among the many improvements cited are: (1) Instruments and controls at approximately room temperature; (2) improved insulation design; (3) there are 36 steps of control; (4) recessed position of controls affords full protection; and (5) instruments are easily accessible through removable panels.

This newly designed furnace uses cylindrical shape shell.

Allyl Starch Makes Tough Flexible Finish

Allyl starch is now available in semi-commercial quantities, according to the *General Mills Research Laboratories*, General Mills Bldg., Minneapolis, Minn. Allyl starch, which was originally developed by the Eastern Regional Research Laboratory of the U. S. Department of Agriculture, is an unsaturated starch ether containing approximately 1.7 allyl groups per glucose unit. It is soluble in alcohols, ketones, esters, halogenated hydrocarbons, nitroparaffins, ethers, toluene, Hi-flash aromatic naphthas, and in other aromatic hydrocarbons when a small amount of a hydrogen bond-forming solvent is present. Allyl starch is normally insoluble in aliphatic hydrocarbons; however, these hydrocarbons can be used as a diluent when the mixture contains a small percentage of high boiling active solvent.

As a baked lacquer or enamel, this new formulation has produced hard, tough and flexible as well as water-resistant films. Normally, the compound will bake to a hard, durable, solvent resistant coating in 90 min. at 230 F or 45 min. at 255 F, but its baking time can be shortened to 1 or 2 min. at higher temperatures.

Since its introduction, allyl starch has found a place in such industrial products as printing inks, specialty adhesives, overprint varnishes and heat-resistant oven finishes. The heat resistance of allyl starch has created interest in the product for finishes on automobile exhausts, automobile and diesel engines, steam radiators, oil refinery equipment, and metal smoke stacks.

As an overprint varnish, allyl starch, which dries quickly, has formed hard, glossy films. Because these films are resistant to solvents, acids, soap and water, they have been used successfully as a coating for beer cans.

In coatings, for industrial and marine equipment, allyl starch compositions containing pigment or metal, such as aluminum powder, have produced hard films with high lustre and excellent resistance to solvents and high temperatures. Allyl starch coatings have remained on the inside of high-temperature baking ovens for more than 90 days without showing signs of deteriorating, yellowing or blistering. Other allyl starch coatings have survived long periods in standard salt cabinets, where they were exposed to continuous and intermittent sprays of 20% sodium chloride.

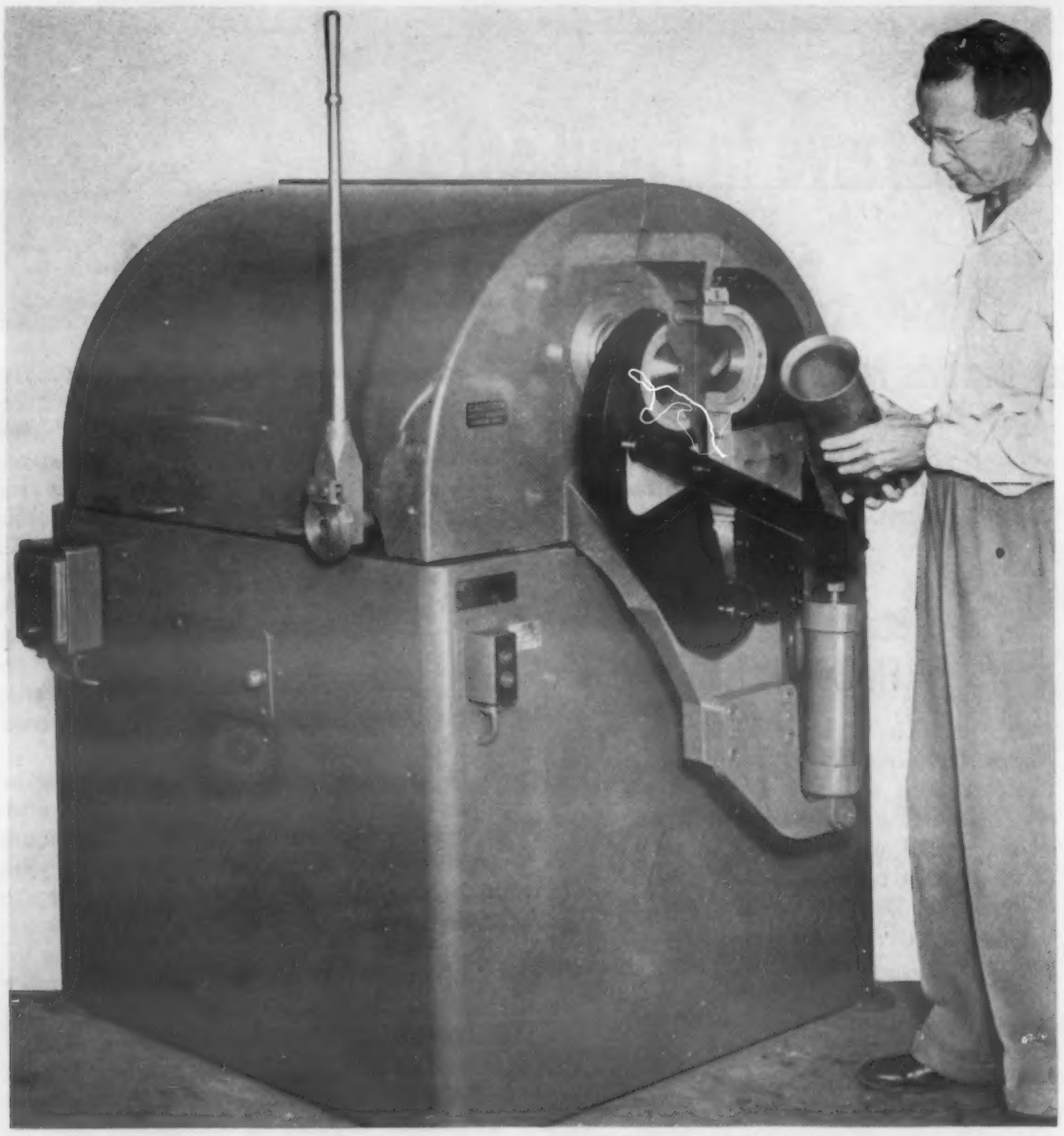
● *Alloy Rods Co.*, York, Pa., has announced two new developments—a new a.c.-d.c. stainless electrode, and a new all-steel, moisture-proof and grease-proof electrode container. The new container is said to simplify stock problems and eliminate moisture damage to electrodes. It comes in 5- and 10-lb. sizes, designed to hold just the right amount of electrodes for typical welding jobs.

New Materials and Equipment
(CONTINUED)

Tube Flaring Machine Built for Large Diameter Stock

A new tube flaring machine that has a capacity for flaring, flanging, squaring and burring, either ferrous or nonferrous tubing, ⅛ to 5 in. in dia., has been developed by the *Leonard Precision Products Co.*, Garden Grove, Calif. Adaptors are furnished with this new model Tubemaster so that present users of the smaller capacity machine can utilize their present tools and dies. Where required, tooling is also available for beading operations.

The new model is powered with a 2-h.p. motor and varispeed drive, which gives a very wide range of from 70 to 550 rpm., for the handling of a variety of materials.



Here shown is the new tube flaring machine, a typical flaring job done on it.

Tester Determines Micro Hardness of Minute Particles

A new tester for micro hardness testing has been announced by *Kent Cliff Laboratories*, Peekskill, N. Y. Known as the Kentron Micro Hardness Tester, it is the first tester to apply accurately dead weight loads as light as 1 gm., for use with either the Knoop indenter or the Vickers type indenter.

This method of applying a 1-gm. dead weight load makes possible micro hardness testing of minute particles, inclusions, constituents, thin metals, transition zones of welds, wire, foil, ceramics, glass, enamels, plastics and jewels, both natural and synthetic.

The tester is a bench type instrument and is hand-operated to eliminate instrument-operating vibration. An adjustable oil dash pot, for controlling the speed of load application and time of load retention, is easily adjusted to suit specific testing requirements. A specially built mechanical stage consisting of three basic parts—the stationary plate, transfer plate and specimen block—provides means for positively locating and positioning the exact area of the test specimen underneath the indenter and microscope.

Dead weights for applying loads of 1 to 1000 gm. and the most up-to-date optical measuring equipment are supplied as standard equipment.

● *Western Felt Works,* Chicago, has announced that it has gone into production on a new material, Westsorb, developed to eliminate vibration on all types of machinery. Advantages are the elimination of floor bolts to anchor machines, ease of mounting, and ease of relocating machines and production lines. Westsorb is available in three densities and ½-, ¾- and 1-in. thickness to satisfactory mount any machine. It is made from specially selected, uniformly blended wools.

New Process Bonds Dissimilar Materials

A process for bonding dissimilar materials in parts designed to withstand high lateral or internal hydrostatic and aerostatic pressures has been developed by *Western Sealant, Inc.*, 9091-3 W. Washington Blvd., Culver City, Calif. It is a batch immersion method, primarily for bonding plastic or neoprene to metals, or ferrous to nonferrous metals, as in bushings or inserts used in aircraft, electronic, oil tool, or hydraulic equipment industries.

In addition to bonding, the process also eliminates microporosity by impregnation with the bonding agent, which has a wide range of resistance to operational temperatures and chemical solvents. Finished parts show no visible signs of treatment, and anodized, plated or machined areas are not affected.

Such dissimilar materials as glass to metal, neoprene to metal, plastic to metal, steel inserts in aluminum, aluminum to aluminum, and brass to aluminum have been bonded by this process. At present, parts are being processed only at the Western Sealant plant, but equipment ranging from bench size to large production units is available.

New Materials and Equipment

New Welding Developments

Arc Welding Generators

A new series of a.c. and d.c. welding generators has been announced by the *Miller Electric Manufacturing Co.*, Appleton, Wis. These new models are available either as engine driven or electric motor driven units. The d.c. models are available with a welding current range from 30 to 400 amp., and the a.c. models from 15 to 300 amp.

One of the new series of Miller Welding generators.

Both the a.c. and d.c. generators have dual controls, separate excitation, instantaneous voltage recovery, and easy arc starting. The engine driven a.c. models (models AEA-250 and AEL-250) are available with built-in high frequency for inert-gas-shielded arc welding.

In the motor driven units—both a.c. and d.c.—the motor is a squirrel cage type with cast aluminum rotor, across the line starting, and operates on either 220 or 440 v. The motor driven a.c. and d.c. models are available either stationary or with a steel wheeled running gear for portability.

Welder for Light Gages

A small arc welder, operating off a 110-v. light circuit is now available from the *Lincoln Electric Co.*, Cleveland 1, for repairing and fabricating in light gage metals.

With a maximum output of 60 amp., the Lincwelder 60 can be used for a variety of light gage metal working jobs, as well as for joining heavier material such as strap, pipe tubing, angle and other shapes. The unit can also be used for cutting metals, soldering and making wire connections, brazing, heating for bending and, with a small rectifier, for battery charging. For repairs and fabricating in sheet metal it offers a method of welding, soldering and brazing that is said to be faster, easier and better than convention methods. Arc welding reduces distortion difficulties in welding metal as thin as 20 gage. The welder op-

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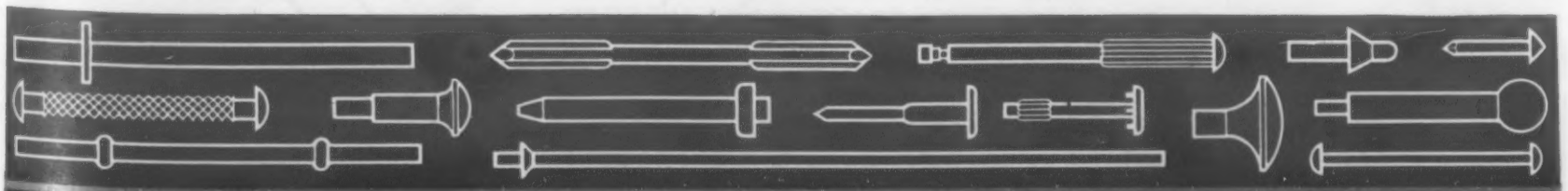

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New Materials and Equipment

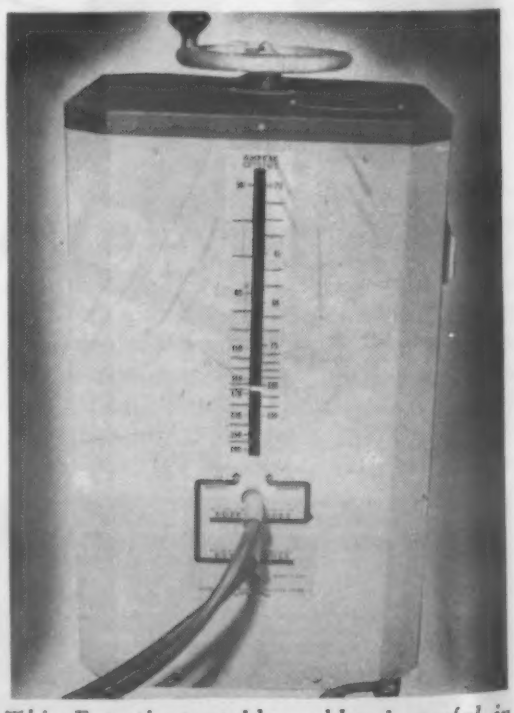
This Lincoln welder weighs only 50 lb.

erates off the standard 110-v. light circuit fused for 30 amp., and weighs approximately 50 lb. It can be carried by its handle, plugged into the nearest light socket and used wherever it is needed.

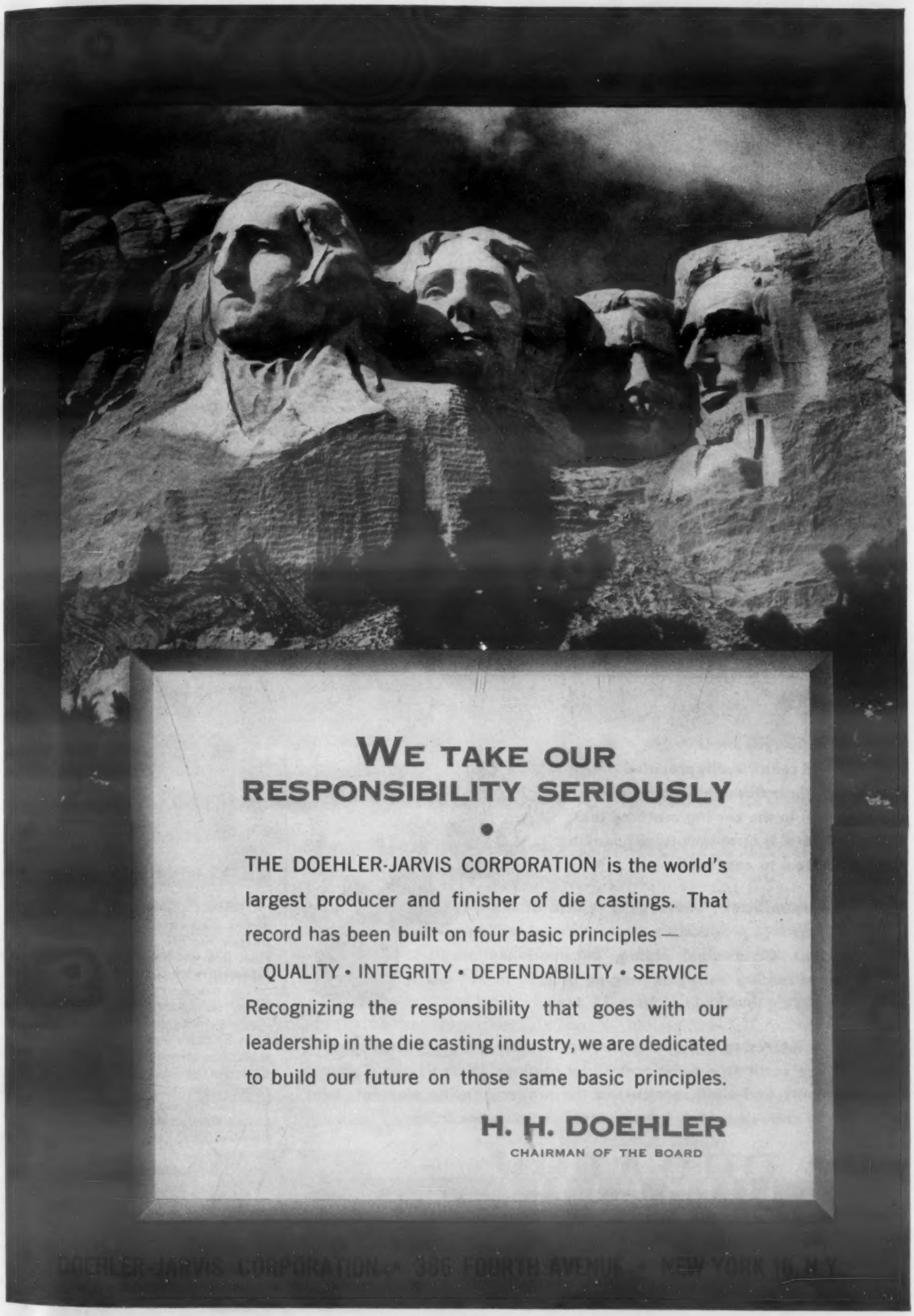
Portable Arc Welder

A newly designed double duty welder has been placed on the market by the *Eutectic Welding Alloys Corp.*, 40 Worth St., New York 13. This standard 200-v. machine has stepless control for adjustment of current and can be used to weld on light and relatively heavy gage materials.

The welder is mounted on casters, which permit transportation around the shop from one job to another. Its overall dimensions are 17 by 17 by 32 in. Its amperage selector control of current allows selection of small amounts of current, ranging from 20 amp. to 285 amp. Other features claimed are:



This Eutectic portable welder is useful in small shops for fabrication and repair work.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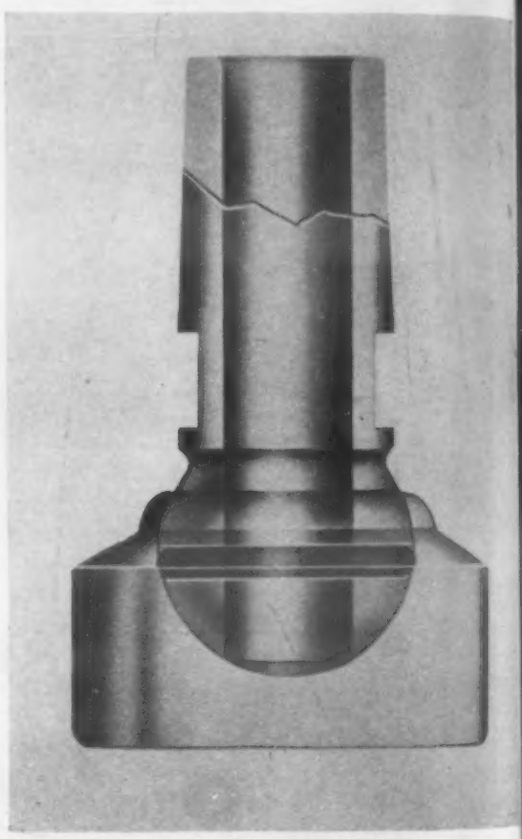
New Materials and Equipment

easy starting, stable arc characteristics, low spatter loss. It accommodates electrodes from 1/16 to 1/4 in. in dia.

New Electrodes

Improvement in performance of swivel type resistance welding electrodes is said to be possible with a new design by *P. R. Mallory & Co., Inc.*, Indianapolis, Ind. In the new design, the water hole is drilled completely through the shank, bringing cooling water directly in contact with the swivel head. Tests indicate a stabilized operating temperature of 200 F for the new unit, compared with 630 F for the earlier

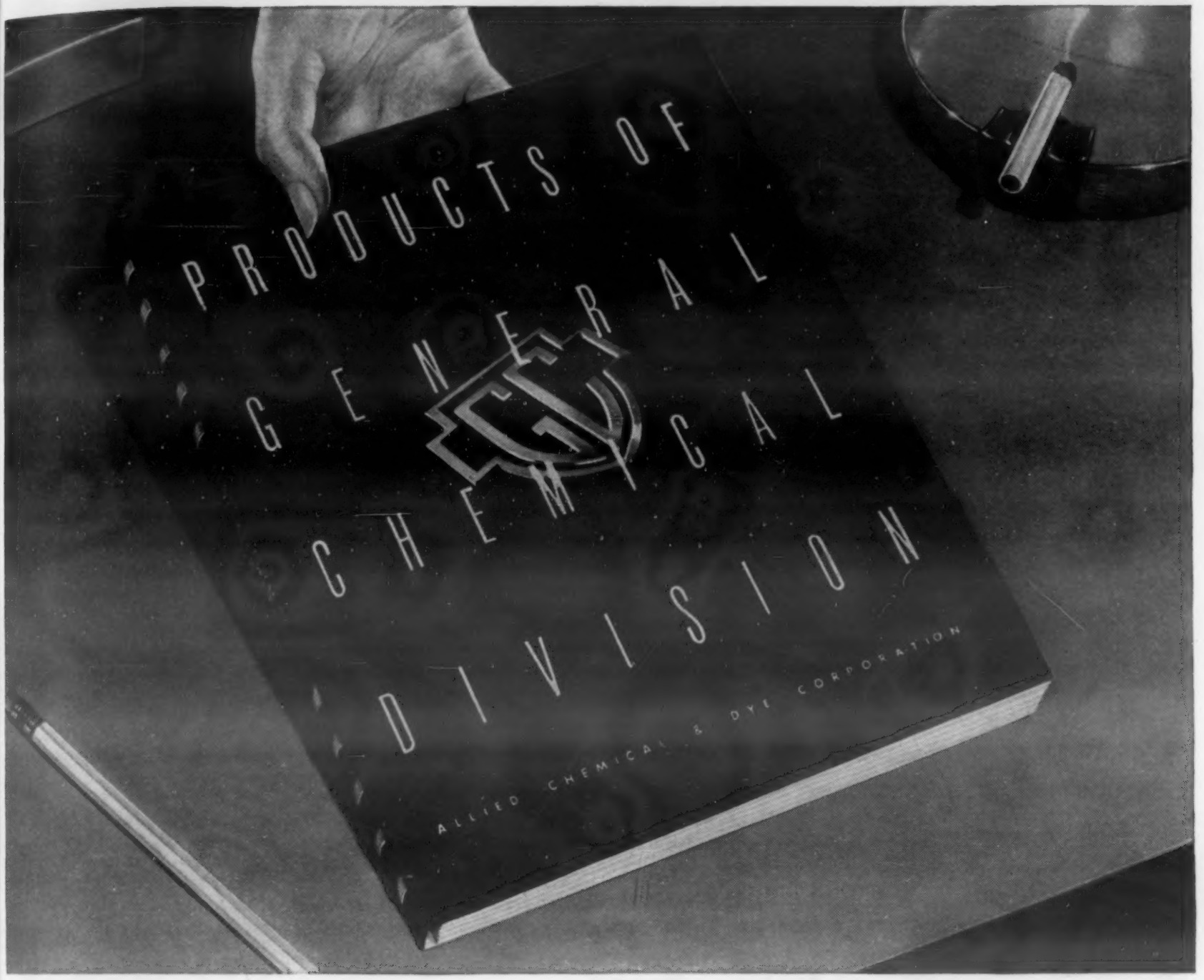


Interior view of the Mallory electrode.

design. This reduction is said to materially increase the life of the swivel tip and enables it to produce more sound welds of a higher strength.

Two new electrodes have been announced by the *Hobart Brothers Co.*, Troy, Ohio. The one, designated Hobart No. 313, is a Class E-6013 electrode designed for making short, intermittent welds at high speed on all gages of steel in any position using either a.c. or d.c., straight or reverse polarity. The arc can be easily started and restarted without scraping or hitting the electrode against the work surface. The tendency for this type of electrode to stick to the work piece has been eliminated in this electrode. It is available in 12-in. lengths in 3/32 in. only and 14-in. lengths in 1/8, 5/32 and 3/16 in. sizes.

The other electrode, Hobart No. 384, is of the Class E-6020 type. It is designed for making high-speed tack welds on heavy weldments without the necessity of breaking the excess coating from the end of the



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New Materials and Equipment

electrode each time the arc is started or restarted. It will be found that in most cases a mere touching of the end of the electrode to the work piece is sufficient to restart and maintain the arc. The coating has sufficient dielectric strength to withstand scraping against the work piece or ground without arcing through. This electrode is also good for scrap cutting with the electric arc. It is available in 14-in. lengths in 1/8-, 5/32- and 3/16-in. sizes and 18-in. lengths in 1/4-in. size.

Inert-Arc Electrode Holders

Six new electrode holders for the inert-gas-shielded arc process, one for machine welding and five for manual welding, have been announced by the *General Electric Co.'s Welding Div.*, Schenectady 5, N. Y. The manual holders are available in 100-, 200-, 400- and 800-amp. ratings, and the holder for machine welding in ratings of 400 and 800 amp.

The new electrode holders for manual welding are: a 100-amp. air-cooled model with spring-type collets, metal nozzle, and gas-tight, heat-resistant gasket; 200- and 400-amp. water-cooled models with split-copper collets, ceramic nozzles, and gas-tight, heat-resistant gaskets; a 400-amp. model with integral water-cooled metal nozzle, furnished with tips of two orifice diameters; and an 800-amp. model furnished with one electrode assembly for each size listed and with three water-cooled metal nozzles, one for 5/16- and 3/8-in. electrodes, one for 7/16-in. electrodes, and one for 1/2-in. electrodes.

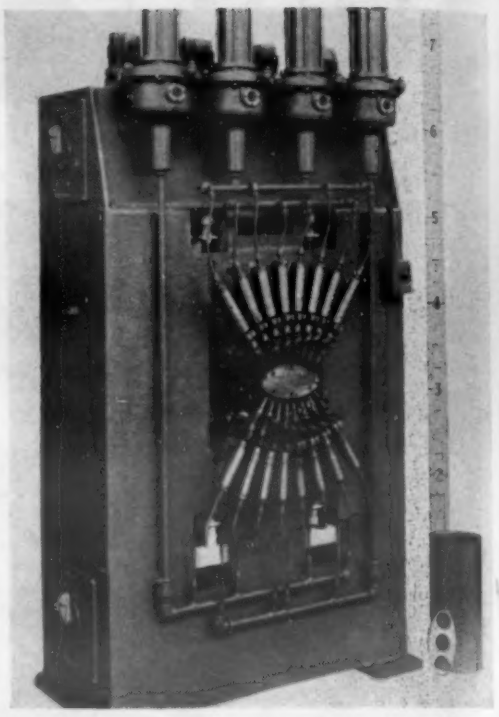
For machine welding the new 400-amp. water-cooled electrode holder comes furnished with one piece of each size of tungsten and one set of collets for each size. With this holder the electrode can be adjusted while welding, and both the electrode and collets can be changed without removing the nozzle.

Multiple Electrode Resistance Welder

A 16-gun multi-speed resistance welder has been developed by the *Taylor Winfield Corp.*, Warren, Ohio. This type of multiple electrode resistance welder is designed to take advantage of the compact hydraulic gun, at the same time eliminating the need for a hydraulic pumping unit. Air-oil boosters operate through air valves working in sequence, connected to the main air supply to provide welding force. Each welding gun passes welding current when a contactor, actuated by the sequencing mechanism, energizes the primary of the welding transformer.

The machine illustrated welds baffles in automobile mufflers made of 0.040-in. zinc coated steel at the rate of 480 mufflers per hr. It makes 16 welds per muffler in four

New Materials and Equipment



This Taylor Winfield resistance welder is being used to fabricate automobile mufflers.

progressive groups of four welds per group, for a total of 7680 welds per hr. Two pairs of series welds (four welds) followed by a like set of four welds, a total of eight welds, are made on top the muffler. In sequence, two groups of welds, or eight welds, are made on the bottom. This sequence welding eliminates the need for an internal expanding work arbor. Each of two 50-Kva. transformers makes two series welds per group.

Spotwelding Machine for Cans

A spotwelding machine has been designed by the *Acro Welder Manufacturing Co.*, Milwaukee, Wis., which automatically welds two cans together at the rate of 160 cans per min.

The machine, developed for *S. C. Johnson & Son, Inc.*, is completely automatic and can be placed in the filling, capping and packaging production lines where it takes single cans from the standard conveyor and puts paired cans back on the standard conveyor at the rate of 160 cans per min.

A spot weld is produced at the top rims and at the bottom rims of each pair of cans where rims contact each other. The spot welds are accurately controlled by electronic weld sequence controls.

Carefully developed relationship between weld heat, weld time, weld pressure, weld area, electrode shape and electrode cooling eliminates the difficulties arising from the inherent tendency toward electrode pick-up from the electrolytic tin plate can rims. An average of 14,400 consecutive welds can be made in continuous production before brief interruptions for electrode dressing or replacement is necessary.

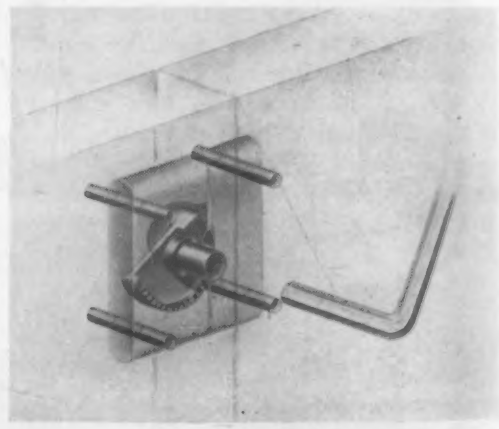
New Materials and Equipment

New Fastener for Honeycomb and Sandwich-Type Materials

A new butt-joint panel fastener, designed to overcome many of the fastening problems encountered in demountable boxes, movable and permanent partitions, and all panel construction work, has been developed by the *Simmons Fastener Corp.*, Albany, N. Y. Known as the Roto-Lock, it is useful in connection with honeycomb panel or other sandwich-type materials, as well as plywood, marinite and masonite.

The principal feature of the fastener is its tapered cam design. It incorporates no spring or other delicate mechanical parts that would be affected by severe temperature conditions. All parts have high resistance to corrosion and wear.

The design of the male and female components of the fastener enables it to be used to attach vertical to horizontal panels. This permits its use for attaching roof to side panels, side panels to floor panels, and any panels to structural members. It will draw panels together at sufficient pressure to establish an air- and water-tight seal, and will carry a 1400-lb. tension load.



Phantom view of new butt-joint panel fastener.

Due to its tapered cam design, it will also carry heavy shear loads.

It will fasten in seriously misaligned conditions in all directions. In the event of an incompressible obstruction between panels being drawn together, the Roto-Lock will lock in any semi-open position necessitated by the obstruction.

● Introduction of plater's bar, a highly refined and closely processed product used in the jewelry trade by manufacturers of rolled plate, is announced by *Revere Copper & Brass, Inc.*, 230 Park Ave., New York 17. The bar is available in a complete range of sizes and a wide variety of copper alloys. The base metals are supplied in shades to complement the precious metals with which they are clad by the plate manufacturers.

New Materials and Equipment

Synthetic Vehicle Improves Diamond Abrasive Compound

A new diamond abrasive manufactured by the *Industrial Products Div., Elgin National Watch Co.,* Aurora, Ill., was introduced recently. The newly developed synthetic vehicle used in the preparation of the compound is said to greatly expand the field of economical application for diamond abrasives.

Advantages of this diamond compound are due to the synthetic vehicle which carries the diamond abrasive and precise size grading of the actual diamond particles. Only pure virgin diamond is used. Accurate grading minimizes the presence of under-size or over-size particles and assures rapid, uniform cutting action. According to its manufacturers, the compound permits the use of standard time analysis procedures in connection with lapping and polishing operations.

The new synthetic vehicle is said to resist caking or drying out, is universally soluble in commercial solvents and water, and leaves no dulling film on finished surfaces. Another advantage of this new vehicle is an increased range of temperature stability, from 150 to -50 F, which permits machine lapping with diamond abrasives for the first time.

Typical uses are finishing carbide and hardened steel parts, plastic molds, drawing dies, bearing surfaces, precise lapping of hardened gages, and polishing the cutting edges of all types of cutting tools for increased tool life.

Spray Washers Designed for Later Additions

A series of new metal parts washers to its present line of cleaning equipment and chemicals has been announced by the *Detrex Corp.,* Detroit 32. The new washers feature standardized construction so that multiple wash, rinse and dry-off stages can be incorporated at minimum cost. They are designed so that if only spray stages are installed originally, a blow-off stage can be added at any time later.

These machines—the WB-100-S, single-spray-zone unit and the WB-200-S, two-spray-zone—can be used as standard metal parts washers for ordinary alkali cleaning compounds, or can be converted to efficiently handle those compounds which have a tendency to foam excessively.

The work is pressure-sprayed with clean-

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1. Stove Venturi Tubes
2. Bicycle Handlebars
3. Tubular Handles
4. Shock Absorber Cylinders
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7. Fire Extinguisher Cylinders
8. Mirror Arms
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Bearing shells to wheel hubs . . . fire extinguishers to venturi tubes . . . here are but a few of the countless products which are made better, easier, and at lower cost with strong, dependable Republic ELECTRUNITE Mechanical Tubing.

Perhaps you, too, are using, or are planning to use tubing in existing or in anticipated products. In either case, you'll find ELECTRUNITE Tubing unsurpassed for uniformity, ease of fabrication and ability to take any form of plated or painted finish readily and economically. It is *available* in a wide range of sizes, gages and analyses—in both carbon and stainless steel.

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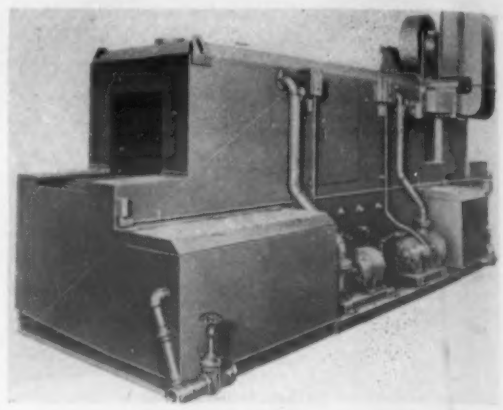
New Materials and Equipment

ing solution from multiple spray headers. Spray nozzles are readily accessible for cleaning, and are adjustable so that they can be directed to any given point. All spray headers are provided with removable plugs.

The spray off-fall is directed by means of shed plates through removable mesh-



The steam-heated, two-spray zone washer equipped with belt conveyor and having steam-heated blow-off section at right.

type chip baskets into a settling sump, then through removable screens into the main tank, where the solution is heated by a bank of steam coils before it re-enters the pump suction.

The blow-off stage, for both the single and double-spray-zone machines, can be steam or gas heated, or built to give cold-air blast, whichever is required. The position of each blow-off nozzle is adjustable so as to strike the work at any angle desired to give most effective drying.

Multi-Barrel Tumbler Designed for Mass-Finishing

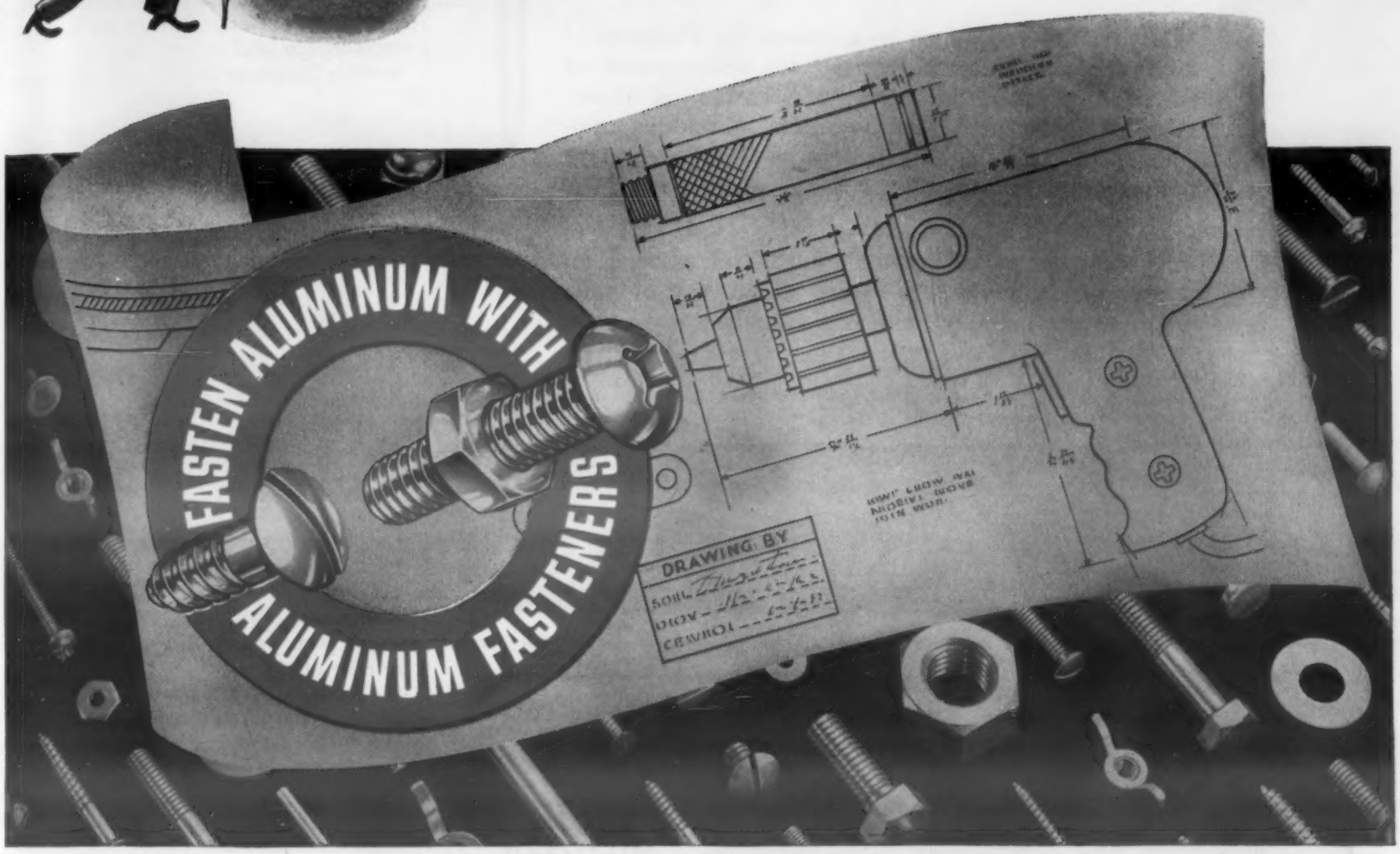
A new type of deburring and polishing machine, for mass-finishing of metal and plastic products, has been announced by the *Hungerford Corp.*, Big Flats, N. Y. With this equipment, up to 15 different items can be handled at the same time, without mixing, and each can be tumbled in the manner best suited to its requirements.

The variables include wet and dry tumbling; wide range of speeds; rotary, centrifugal and end-to-end actions; and combinations of these actions. Thus, all degrees of contact and impact can be obtained, and delicate parts, which heretofore required deburring and polishing by hand, can be machine-processed without danger of deformation.

A circular mounting plate, with multiple perforations at center and six distances

AVOID "JOINT TROUBLE"

IN ALUMINUM ASSEMBLIES



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There's no need to run the risk of the galvanic corrosion that can come when aluminum is fastened with dissimilar metals. The complete line of Alcoa Aluminum Fasteners includes all the types required to meet any production assembly need.

Complete ranges of sizes and head types. Slotted or Phillips head. Made to Alcoa quality standards, yet not expensive.

ALCOA *Aluminum* FASTENERS®

New Materials and Equipment

from center for attachment of the barrels, is rotated at a fixed speed. The barrels, of numerous lengths and diameters, are of round, hexagonal, clover-leaf, or special cross-section, and can be furnished with or without Neoprene lining. They are mounted

One of many different types of barrels being fastened to the circular mounting plate.

at right or other angle to the plate, as an added factor in providing wide selection in severity of action.

Center mounting produces a mild rotary action, and selective distances from the center add centrifugal action in desired degree, according to increasing periphery speeds. The angle mounting introduces end-to-end action, as well as rotary and centrifugal actions.

● A plastic foam, that expands to 100 times its original volume when baked, has been developed as a new insulating material at the *Westinghouse Research Laboratories*, East Pittsburgh, Pa. Lighter than some gases, it is resistant to fire, moisture, fungus growth and insects, and is low enough in cost to be practical for many applications. The foam is made from a synthetic phenolic resin, is reddish brown in color, and has a sponge-like appearance.

Plastic Coating on Welded Tube Has High Corrosion Resistance

Development of a new electric welded steel tubing, coated with a plastic type rust-resisting finish, has been announced by the *Jones & Laughlin Steel Corp.*, Pittsburgh 30. The new product will have application in the manufacture of inexpensive outdoor structures and other applications where light wall steel tubular members are exposed to corrosive atmosphere. Known as Permatube, it can be fabricated by bending, ex-

What's the right X-Ray film?

Product:

Drive wheel

Material:

Cast steel

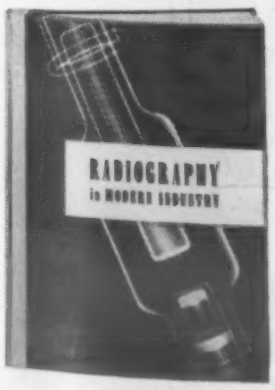
Equipment:

250-kv x-ray unit

ANSWER:

KODAK INDUSTRIAL X-RAY FILM, TYPE F

Because the equipment had only moderate power and section thicknesses up to 3¼ inches were to be examined, the radiographer chose Kodak Industrial X-ray Film, Type F, exposed with Kodak Industrial X-ray Intensifying Screens. This film is designed for use with fluorescent screens to provide maximum speed. The combination is essential in boosting equipment capacity to handle a heavy job like this. And, since the examination is for gross defects, speed is more important than sensitivity to very fine detail.



RADIOGRAPHY IN MODERN INDUSTRY

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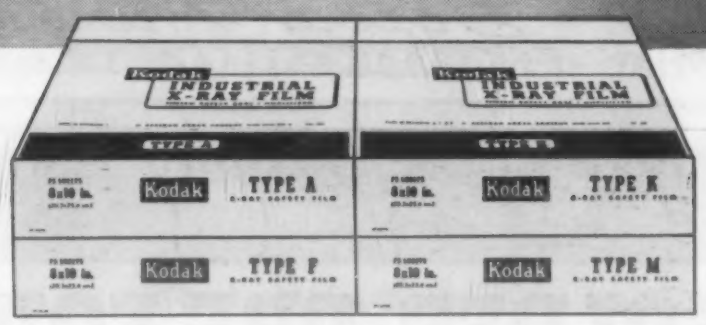

A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film.

Type F gives the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type M provides high contrast and exceptional detail under direct exposure or with lead-foil screens. It has extra-fine grain, and speed is adequate for radiography of light alloys at moderate kilovoltages and for much million-volt work.

Type A offers high contrast with about three times the speed of Type M, but with slightly more graininess. Used direct or with lead-foil screens for study of light alloys at lower kilovoltages, and of heavier steel parts at 1,000 kv and with gamma rays.

Type K has medium contrast with high speed. For gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without use of intensifying screens.

EASTMAN KODAK COMPANY
X-ray Division · Rochester 4, N. Y.

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Radiography

another important function of photography

Kodak

New Materials and Equipment

panding, flanging, upsetting, fluting and flattening, without damage to the finish.

In accelerated salt spray tests the tube did not corrode until more than 2000 hr. of exposure in accelerated salt spray tests and, in some cases, lasted 3000 hr. before any corrosion appeared. When subjected to the standard A.S.T.M. weatherometer test—which reproduces weather conditions such as exposure to sun rays, heat, humidity and rain—it showed no corrosive effect after a test period which the testing laboratory evaluated as equivalent to more than 5 yr. actual exposure. The coating was found to be equally stable and unaffected by low temperatures. Initial humidity tests of the tube are still in progress after more than 1000 hr. exposure to a 100% relative humidity at a temperature of 130 F.

This new plastic coated tube can be cold-formed to the limits of the steel before the coating chips, cracks or flakes.

Perma-tube is coated with a special finish consisting of Vinsynite pretreatment and a vinyl resin base, developed by *Thompson & Co.*, Oakmont, Pa. The pretreatment adheres tightly to the steel surface, phosphatizes the metal, and deposits a very thin film (about 0.0003 in.) of protective coating over the phosphatized surface in one operation. It is applied to the steel tubing by dipping. An appropriately pigmented vinyl resin base, which has a dried film thickness of about 0.0015 in., is applied over the pretreatment.

Continuous Limit Gage Checks Strip and Sheet Material

To protect metal stamping dies from being injured by material that is too thick, *Pratt & Whitney*, Div. of *Niles-Bement-Pond Co.*, West Hartford, Conn., have developed a new continuous limit gage which indicates or controls by a signal light, control relay, or the like, when the strip or

DOWNTIME BLUES ?

Use

BTR

THE SAFE-HARDENING TOOL STEEL FOR LONGER DIE WEAR

Downtime is time forever lost. Specify BTR (Bethlehem Tool Room) for those longer runs and cut your downtime by increasing production between grinds. BTR is high in wear-resistance. But it's an easy steel to machine. And heat-treaters like the way it hardens in oil from 1475 F with minimum distortion.

BTR is deep-hardening, holds a durable cutting edge. It's a general-purpose steel for a wide range of tools and dies. Best of all, BTR is economical. Try it on your next job and you'll probably find, as many others have, that it replaces several grades you're now using.

Call the nearest Bethlehem Tool Steel distributor or Bethlehem sales office. Prompt deliveries from local stocks.

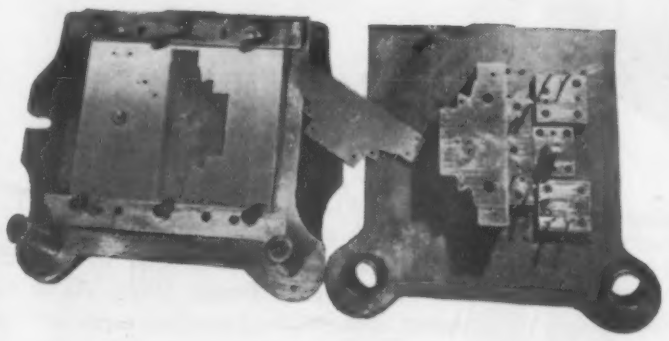
TYPICAL ANALYSIS:

C	Mn	W	Cr	V
0.90	1.20	0.50	0.50	0.20

HEAT-TREATMENT:

Anneal at 1450 F, furnace-cool, 202 Brinell
Harden at 1475 F, quench in oil
Temper from 325 to 400 F for a working hardness of 58 to 62, Rockwell C

AS AN EXAMPLE



... here's a blanking and piercing die—made from BTR—which produces end sections of 19-gage steel for fluorescent lamp fixtures. Its excellent wear-resistance is shown by the production of about 300,000 pieces between grinds. The dies will have a long life, for only 0.005 inch is removed when they are redressed, about three times a year.

Photo through courtesy of Westberg Tool and Manufacturing Co., Bridgeport, Conn.

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BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

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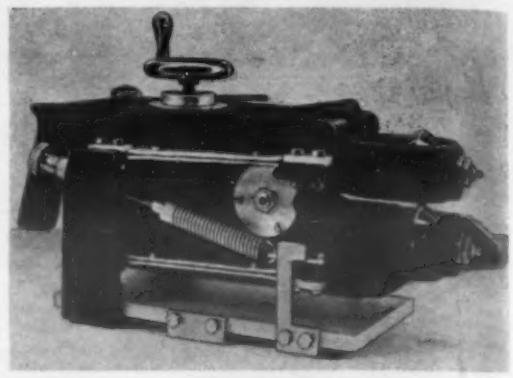
BETHLEHEM STEEL

BTR ... one of Bethlehem's fine tool steels

New Materials and Equipment

sheet material is too heavy. This gage does not show the thickness of the material or the amount of variation, but rather indicates when the material is light or heavy, not both.

When this gage is used with a die stamping press or similar machine, it will send out a signal or impulse that will stop the



Principal purpose of this continuous limit gage is to prevent injury to metal stamping dies.

operation before the heavy material reaches the die. Also, this gage provides a means of inspecting continuous strip material where it is desired to control only one limit, high or low.

The range of the gage is from 0 to 0.300 in., with an accuracy of 0.0005 in. The gage is set by means of precision gage blocks and by turning the hand wheel until the setting light is on or just ready to come on.

Spotweld Nuts and Screws Are Handy Fasteners

Fasteners and fittings for attaching to sheet steel surfaces by using projection welding have been developed by the *Ohio Nut & Bolt Co.*, Berea, Ohio. As is well known, spot welding machines can be either the rocker-arm or press type. Spot welding is used in many instances to "tack" the fastener or fitting in place on products where the design throws no particular stress or load upon the welded joint.

Seven sizes of nuts, ranging from No. 8-32 up to and including 5/16-18 threaded hole, are now available. Also, 63 production sizes of screws can be had in production quantities.

Stock sizes of the nuts and production sizes of the screws are designed for use with the commercial thicknesses of sheet steel. The nuts are made of low carbon steel; the screws are made either of low carbon steel, high brass or stainless steel.